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Research Note

FOREST AND RANGE EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE • PORTLAND, OREGON

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THE OCCURRENCE OF THE HEMLOCK LOOPER (*LAMBDINA FISCELLARIA* (GUENÉE))
(LEPIDOPTERA: GEOMETRIDAE) IN SOUTHEAST ALASKA,
WITH NOTES ON ITS BIOLOGY

by

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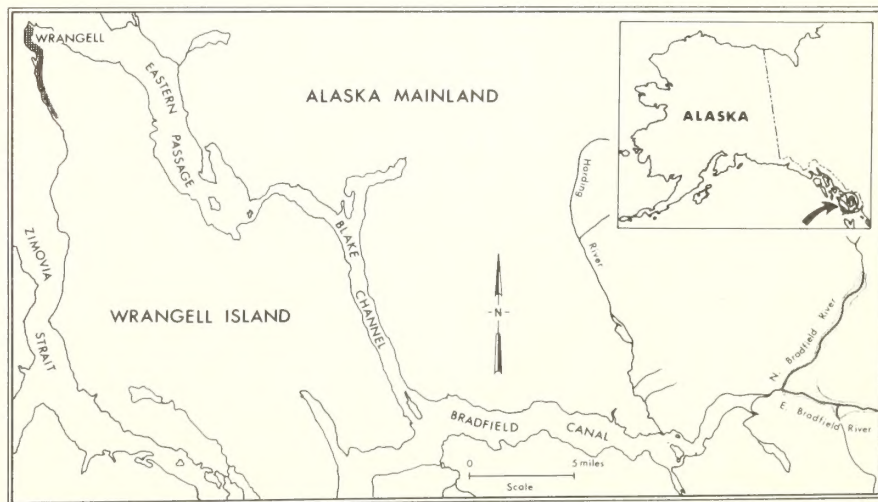
and

Bruce H. Baker, Entomologist, Region 10,
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INTRODUCTION

In August 1965, a hemlock looper (*Lambdina fiscellaria* (Guenée)) infestation was discovered by Wrangell Ranger District personnel in river bottom stands of Sitka spruce (*Picea sitchensis*). These stands were located about 40 miles southeast of Wrangell, Alaska, on the lower north and east forks of the Bradfield River in the North Tongass National Forest (fig. 1). Within the infestation there were about 396

Figure 1.--Map of portions of Wrangell Island and the Alaska mainland, showing location of the hemlock looper infestation (shaded area) on the Bradfield River.



acres of heavily defoliated spruce which could be seen as rust-colored patches of damaged trees. Moths reared from eggs collected in the area were examined by D. Evans of the Forest Research Laboratory, Victoria, British Columbia, Canada, who tentatively identified them as the western hemlock looper (*L. fiscellaria lugubrosa* (Hulst)). The collection and subsequent identification of the looper is the first record of this insect in Alaska.

A study area of about 12 acres of heavily defoliated spruce was chosen on the east fork of the Bradfield River. Larval collections were made periodically from June 17 to August 11, 1966.

LIFE HISTORY

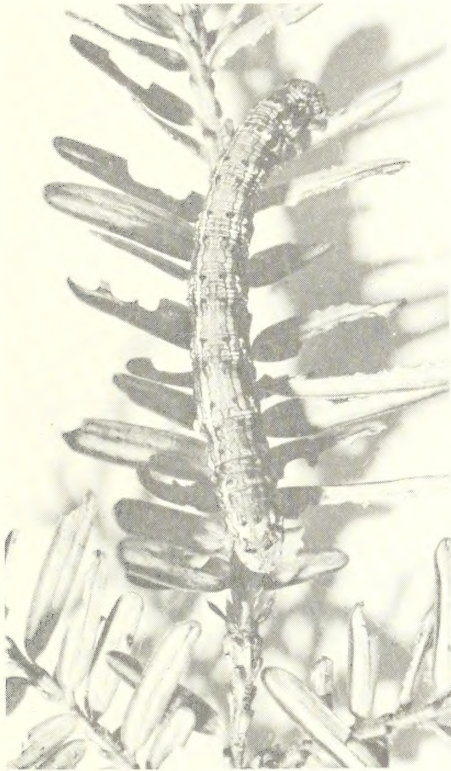
The hemlock looper has one generation per year. The adults (fig. 2) are light-brown or tan moths with a wingspan of 30 to 35 mm.



Figure 2.--Male moth of the hemlock looper from infested Sitka spruce along the Bradfield River, Alaska.

Each forewing has two irregular dark lines and a distinct dark dot. Moths began to appear during the end of August; males emerged earlier than females. Male moths (fig. 2) can be distinguished from females by their plumelike antennae; females have threadlike antennae. The sex ratio is 1:1 (n=897). Although the end of the moth flight and oviposition period was not observed in the Bradfield area, it is probable that adults were present through the end of September. Very little flight was noted during field observations, which probably resulted from the cool, rainy weather at that time. Most of the moths were found clinging to bark scales on the boles of trees.

The looper overwinters in the egg stage. The eggs are small (about 0.6 mm. long), oval, and grayish green with a very finely punctate reflective surface. Eggs are laid on the upper bole and branches, on ground vegetation, and in the lichens and mosses on the lower tree boles.



The eggs hatch during the first or second week in June and the newly emerged larvae move upward and outward in the crown where they begin to feed. First-instar larvae are about 5 mm. long and have distinct transverse bands of black and white on the body. The later instar larvae have various patterns of lines, stripes, and spots giving them a mottled appearance. A distinctive feature in the patterning of late-instar larvae is the presence of four dark spots on each abdominal segment (fig. 3). Preliminary studies indicate that the larvae have four instars in the Bradfield River area. This differs from the findings of Hopping, Thomson, and Carolin,^{1/} who stated that the looper in British Columbia, Canada, and Washington had five larval instars.

Figure 3.--Late-instar hemlock looper larva feeding on western hemlock.

^{1/} Hopping, G. R. An account of the western hemlock looper, *Ellopia somniaria* Hulst, on conifers in British Columbia. Sci. Agr. 15: 12-29, illus. 1934.

Thomson, M. G. Appraisal of western hemlock looper infestations. Forest. Chron. 33: 141-147. 1957.

Carolin, V. M. Studies on western hemlock looper in southwest Washington in 1962. Illus. 1964. (Unpublished progress report on file at the Pacific Northwest Forest & Range Exp. Sta., U.S. Forest Serv., Portland, Oreg.)

Gryse and Schedl^{2/} who worked with the eastern form of the looper in Ontario, Canada, also found five instars. However, Carroll, ^{3/} who worked on the biology of the hemlock looper in Newfoundland, found only four instars. Additional studies will establish the number of larval instars in coastal Alaska with more certainty.

After emerging, young larvae fed on new foliage, but later in the larval development period old foliage was eaten. Often only a few bites were taken out of each needle (fig. 3). The remains of partially eaten dead or dying needles turned reddish brown giving heavily attacked trees a red tinge. Larval feeding and subsequent needle fall stripped many trees completely (fig. 4).

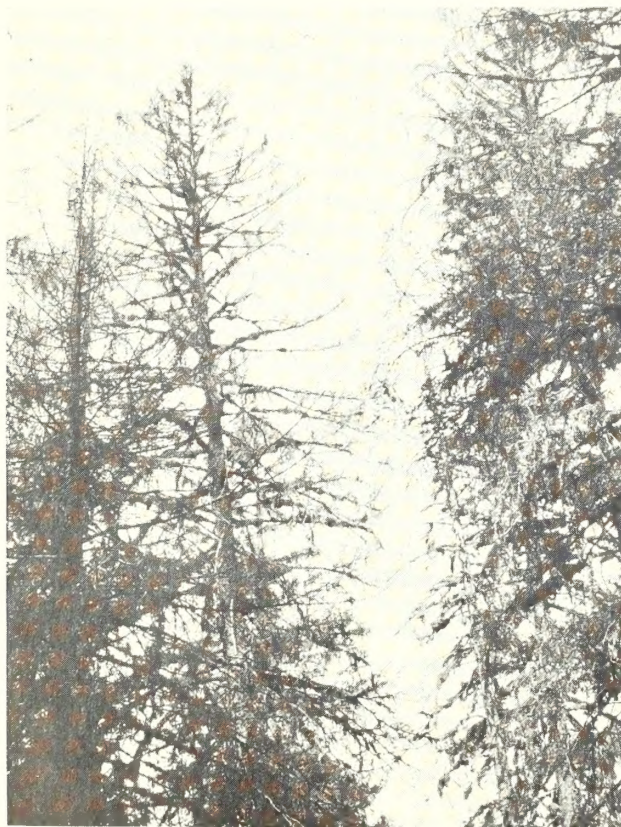


Figure 4.--Defoliated Sitka spruce in infestation area along Bradfield River, Alaska.

^{2/} Gryse, J. J. de, and Schedl, K. An account of the eastern hemlock looper, *Ellopiia fiscellaria* Gn., on hemlock, with notes on allied species. Sci. Agr. 14: 523-539, illus. 1934.

^{3/} Carroll, W. J. History of the hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.), (Lepidoptera: Geometridae) in Newfoundland, and notes on its biology. Can. Entomol. 88: 587-599. 1956.

1-

Sitka spruce was the preferred host in the Bradfield infestation. Western hemlock (*Tsuga heterophylla*) was also attacked, but to a far lesser degree than spruce. Even when overstory spruce was completely defoliated, the codominant and understory hemlock was not heavily attacked. Some feeding also took place on understory species as evidenced by skeletonized leaves. Among the understory plants most commonly attacked were mooseberry viburnum (*Viburnum pauciflorum*), ovalleaf whortleberry (*Vaccinium ovalifolium*), and redosier dogwood (*Cornus stolonifera*).

Defoliation in the overstory trees was evident from the air by mid-July, but was more pronounced by the end of July and early August. This coincided roughly with the peak occurrence of the third instar. Throughout the latter part of the feeding period, larvae were commonly seen descending to the ground and understory vegetation on silken threads.

At the end of the feeding period the late-instar larvae sought pupation sites under moss and bark scales, and in crevices of rotting tree stumps where they pupated. The pupa (fig. 5) is characterized by its tan coloring and dark-brown spots. The pupal period, which began about the end of the first week in August, lasted for 14 to 20 days.

Figure 5.--Hemlock looper pupa.
Final instar larval skin is at
upper right.



NATURAL MORTALITY FACTORS

Field and laboratory studies revealed two sources of looper mortality. Late-instar larvae succumbed to a virus disease, and parasites caused pupal mortality.

Beginning in late July, larvae were noticeably less common in the field. There was heavy mortality among late-instar larvae in the laboratory as well. The disease affecting the larvae was later identified by G. Thomas, University of California, Berkeley, as a polyhedrosis virus.

Insect parasites were also active in the Bradfield River infestation. No adult parasites were recovered from laboratory-reared looper larvae. However, dissections of looper larvae revealed the presence of parasite larvae. The pupal parasite complex appears to consist of about six species. Approximately 27 percent of the looper pupae collected in the field were parasitized.

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A CUMULATIVE CUBIC-FOOT TALLY FORM FOR POINT SAMPLING

by

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Data obtained in point sampling (prism cruising)^{1/} are usually compiled in the office with a desk calculator or by automatic data processing methods. Many times the cruiser would like to know what he is looking at in terms of total gross volume, volume by species, or by size classes. The cumulative tally form presented here enables the cruiser of interior Alaska stands to do this.

The cubic foot:basal area ratios in this tally form were derived from volume tables for interior Alaska tree species.^{2/} Cubic-foot volume, inside bark, is from a 1-foot stump to a minimum merchantable d.b.h. top of 4.0 inches.

Individual cubic foot:basal area ratios were computed by species for each d.b.h. height class. Average ratios by height class were then calculated for poletimber-size trees (softwoods 5.0 to 8.9 inches d.b.h. and hardwoods 5.0 to 10.9 inches d.b.h.) up to the 70-foot class, and for sawtimber (softwoods 9.0 inches d.b.h. and larger and hardwoods 11.0 inches d.b.h. and larger) to the limits of the original volume tables.

^{1/} Bruce, Donald. Prism cruising in the western United States. Mason, Bruce and Girard, Consulting Foresters, Portland, Oregon. 61 pp., 1961.

^{2/} Haack, Paul M., Jr. Volume tables for trees of interior Alaska. U.S. Forest Serv. Res. Note NOR-5, 11 pp., 1963.

Performance of the tally sheet was checked by comparing volume estimates of 34 plots obtained using the cumulative tally with volumes obtained from the original volume tables. Tally form volume estimates were .0052 percent lower than the volume tables with individual plots varying from -.022 to -.072 percent

To estimate gross volume at a point sample location, record each "in" tree by marking through the appropriate volume shown on the cumulative tally form. Volume values are by species and d b h group. If more than one tree is tallied for a given class, mark off the next larger number. Enter the last volume marked in the space provided. Diagonal slashes are provided for keeping the poletimber-sawtimber tallies separate. Determine the total volume tallied for each species (keep these totals separate if per-acre volumes by species are desired) or combine if only one per-acre volume is wanted. To determine gross volume per acre, multiply the total volume tallied by the basal area factor (BAF) used in prism cruising, and divide by the number of points sampled

To determine square feet of basal area per acre, multiply the number of trees tallied by the basal area factor and divide by the number of points sampled

CUMULATIVE TALLY FOR INTERIOR ALASKA TREE SPECIES

(Cu.ft./b.a. ratios)

Project _____ Date _____ Plot No. _____

Cruiser _____ Location _____

Total height	SPRUCE d.b.h. range				Last marked volume	BALSAM POPLAR d.b.h. range				Last marked volume	BIRCH-ASPEN d.b.h. range				Last marked volume	Total height	
	5-8 inch		9 inch +			5-10 inch		11 inch +			5-10 inch		11 inch +				
30	9	18	26	35	10	21	31	41	6	13	19	26	8	16	24	32	30
35	11	22	33	44	12	25	37	50	9	18	26	35	11	21	32	43	35
40	13	26	39		15	29	44		10	21	31		12	25	37		40
	51	64	77		59	73	88		42	52	62		49	61	74		
45	15	30	44		17	34	50		12	24	36		14	28	42		45
	59	74	89		67	84	101		48	60	72		56	70	85		
50	17	33	50		19	38	56		14	28	41		16	32	47		50
	67	83	100		75	94	112		55	69	83		63	79	95		
55	19	38	57		21	41	62		15	31	47		18	35	53		55
	76	95	113		83	104	124		62	78	93		70	88	105		
60	21	41	62		23	45	68		17	34	51		19	39	58		60
	83	104	124		91	114	136		68	85	102		77	97	116		
65	23	45	68		25	49	74		19	38	56		21	42	63		65
	91	113	136		99	123	148		75	94	113		84	105	126		
70	24	49	74		27	53	80		21	42	63		23	46	68		70
	98	123	147		107	133	160		84	104	125		91	114	137		
75	29	57	86		114	143			24	48	73		97	121			75
	172	200	229		257	286			145	169	193		218	242			
80	31	61	92		123	153			26	52	78		104	130			80
	184	215	245		276	307			156	182	208		234	260			
85	33	65	98		131	163			28	55	83		111	138			85
	196	229	261		294	327			166	194	221		249	277			
90	35	69	104		139	174			29	59	88		118	147			90
	208	243	278		312	347			177	206	236		265	295			
95	37	73	110		147	184			31	62	93		125	156			95
	220	257	294		330	367			187	218	249		280	312			
100	39	77	116		155	194			33	66	99		131	164			100
	232	271	310		348	387			197	230	263		296	329			
105	41	81	122		163	204			35	69	104		138	173			105
	244	285	326		366	407			207	242	276		311	345			
110	43	85	128		171	214			36	72	109		145	181			110
	256	299	342		385	427			217	253	290		326	362			
115	45	89	134		179	223			38	76	114		151	189			115
	268	312	357		402	446			227	265	303		341	379			
120	47	93	140		187	233			40	79	119		159	198			120
	280	327	374		420	467			238	277	317		357	396			
	Σ Spruce					Σ Balsam Poplar											

$$\text{B.A./acre} = \frac{\text{No. trees}}{\text{No. points}} \times \text{BAF}$$

B.A./acre = _____

$$\text{Cu.ft. vol./acre} = \frac{\Sigma \Sigma \times \text{BAF}}{\text{No. points}}$$

Cu.ft. vol./acre = _____

TALLY SHEET USE

To obtain gross cubic-foot volume, inside bark, from a 1-foot stump to a minimum merchantable d.o.b. top of 4.0 inches

- 1 Mark the appropriate volume shown on the cumulative tally by species and total height-d.b.h. class.
 - a. If more than one tree per given class, mark off the next larger number for the same class.
- 2 Enter the last marked volume in the space provided.
 - a. Diagonal slashes are for tallying poletimber and sawtimber separately
- 3 Sum the box entries, keeping separate by poletimber, sawtimber, and species, if desired
- 4 Using the sum total or the breakdowns desired:
 - a. Multiply the volume value by the BAF (prism cruising) used.
 - b. Divide by the number of points sampled

To obtain basal area

- 1 Count the number of trees tallied on the form
- 2 Multiply by the BAF used
- 3 Divide by the number of points sampled

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A COMPUTER PROGRAM FOR CALCULATING ALLOWABLE CUT USING AREA REGULATION AND A COMPARISON WITH THE ARVOL METHOD

by Robert W. Sassaman, *Associate Economist*
and Daniel E. Chappelle, *Principal Economist*



INTRODUCTION

Volume regulation is the method most commonly applied to schedule harvest cuts in old-growth Douglas-fir stands in Oregon and Washington National Forests (e.g., it is used on all but one National Forest working circle at the present time). Area regulation also has a place in management planning as a scheduling method and is finding increased interest among forest managers and timberland owners whose main objective is to annually cut an equal forest area.

Recently, a computer program was written that schedules the allowable cut using area regulation. This program, entitled AREA, is a useful analytical companion to the ARVOL program, which was developed earlier to calculate allowable cut using volume regulation.^{1/}

^{1/} Chappelle, Daniel E. A computer program for calculating allowable cut using the area-volume check method. Pacific Northwest Forest & Range Exp. Sta., U.S. Forest Serv. Res. Note PNW-44, 4 pp. 1966. Both ARVOL and AREA are products of the Timber Management Decision Systems (TIMADS) Study. TIMADS, a continuing research effort of the Station and the Pacific Northwest Region, is a long-term study designed to provide forest managers with a more effective planning system.

Use of these two programs can help management planners more efficiently assess the appropriateness of applying volume or area regulation to particular forest tracts.^{2/}

DESCRIPTION OF THE AREA PROGRAM

There are six distinct steps required in the use of the area regulation method. The AREA program, coded in FORTRAN IV, for an IBM 7040 installation, incorporates these steps in computing the allowable cut.

1. Evaluate age class data for the forest in order of cutting priority. This generally means arranging forest stand data by decreasing age.^{3/}
2. Calculate the total area of all stands.
3. Calculate the area to cut each year.
4. Calculate the time required to harvest each stand.
5. Calculate age of stand and yield of stand when cut.
6. Calculate the average annual cut and the cut for each year of the rotation.

In the AREA program the area to cut annually can be calculated with ease once total area and rotation length are known. The years required to cut a given stand are then directly calculated by dividing stand area by acres to be cut annually. In contrast, in ARVOL the allowable cut is calculated in an iterative fashion because it varies directly with the yield of the age class at time of harvesting. The yield of any age class, in turn, depends on age of stands when cut, and the age when cut depends on the cumulated years required to cut the stands. Therefore, a convergence is required to calculate a trial cut that will balance the above factors.

Users of ARVOL should note that input data for ARVOL are interchangeable with AREA. Also, the format of AREA output is nearly identical with ARVOL output, the major exception being that average volume cut for each year of the rotation is shown in a separate table.

^{2/} Area and volume regulation are not the only methods employed in scheduling harvesting operations. The appropriateness of any particular method, of course, depends on how adequately it furthers the firm's goals.

^{3/} **Each age** class is considered to be a stand. However, it is possible that several stands could be the same age.

The program is designed to evaluate a range of alternative rotation lengths. In addition, separate problems, each of which may include the analysis of several alternative rotation lengths, may be stacked and run at one time.

Typical operating times for AREA are as follows:

<u>Number of age classes</u>	<u>Intensive management</u>	<u>Number of alternative rotation lengths</u>	<u>Execution time^{1/}</u> (Minutes)
25	Yes	1	0.40
25	Yes	23	1.05
25	Yes	46	1.75

^{1/} Does not include program compilation time.

COMPARISON OF AREA AND ARVOL METHODS

The area regulation method can be contrasted with volume regulation in two important ways:

1. Volume regulation provides for a constant allowable cut over a rotation period, but the acreage cut per year and, hence, the regenerated acreage per year may vary substantially. In contrast, area regulation provides for an equal acreage cut annually, but the volume cut per year will vary substantially unless the forest is fully regulated.

2. Area regulation provides for an even distribution of area among rotation and younger age classes after one rotation period (i.e., the forest will be fully regulated). In contrast, under volume regulation after one rotation period, considerable concentration of area may be present in some age classes equal to or less than rotation length in age.

In order to exemplify the AREA and ARVOL methods, a sample problem was run with both computer programs using the area and age class arrays in table 1, and assuming a 100-year rotation with a 5-year regeneration period. In this example, 82 percent of the total forest area contains timber above rotation age at the beginning of the plan period, and certain intermediate age classes are nonexistent. The sample problem output revealed that under volume regulation, old-growth timber (i.e., over rotation age) is harvested in 98 years (see column 9, table 1) and in 97 years under area regulation (see column 5, table 1). Therefore, nearly the entire planned rotation may be considered a period of conversion from old-growth timber to young-growth timber under both regulation methods.

Table 1.--Computer output from AREA and ARVOL programs

Age class (1)	Area (2)	AREA (area regulation)				ARVOL (volume regulation)			
		Yield per acre (3)	Time required to cut (4)	Sum of time required to cut (5)	Average age when cut (6)	Yield per acre (7)	Time required to cut (8)	Sum of time required to cut (9)	Average age when cut (10)
Years	Acres	Bd. ft.	Years	Years	Years	Bd. ft.	Years	Years	Years
300	20,000	65,000	18.2	18.2	309	65,000	21.7	21.7	311
250	15,000	60,000	13.6	31.8	275	60,000	15.0	36.7	279
200	20,000	55,000	18.2	50.0	241	55,000	18.3	55.0	246
180	13,000	52,910	11.8	61.8	236	52,965	11.5	66.5	241
160	12,000	52,692	10.9	72.7	227	52,824	10.6	77.0	232
120	10,000	50,747	9.1	81.8	197	51,115	8.5	85.6	201
30	7,500	44,782	6.8	88.6	115	45,793	5.7	91.3	118
20	4,000	43,212	3.6	92.3	111	43,970	2.9	94.2	113
10	5,000	41,175	4.5	96.8	105	41,662	3.5	97.7	106
0	3,500	37,043	3.2	100.0	93	37,173	2.2	99.8	94

The results of the sample problem are portrayed in figures 1 and 2. Note that in figure 1 area regulation results in 1,100 acres harvested annually, whereas under volume regulation, the area cut annually varies from 923 acres at year 0 to 1,616 acres by the end of the rotation. This variance is caused by the high concentration of volume in the old-growth stands and by the assumption that stands will be cut by age priority. This increasing trend of acres harvested annually is amplified by the scarcity of intermediate age classes and the subsequent drop in yield from old-growth to second-growth stands.

Figure 1.--Comparison of acres to cut annually using area and volume regulation

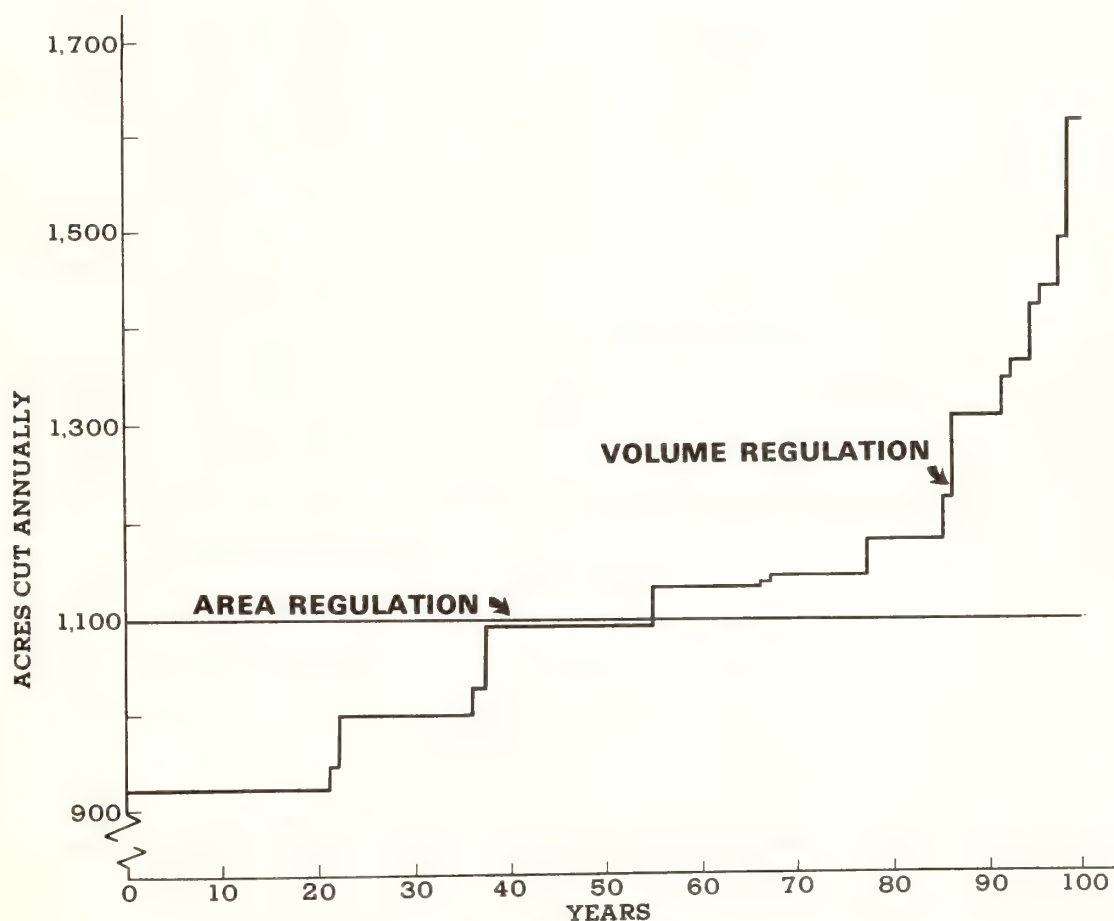
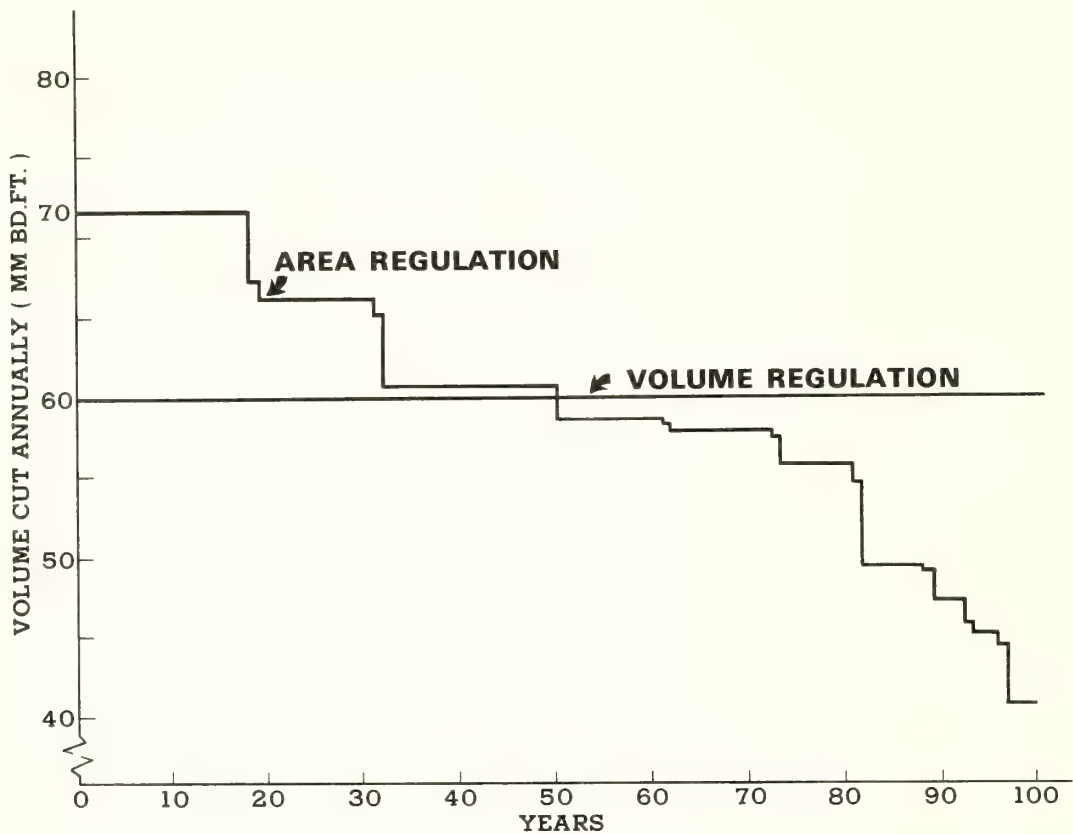


Figure 2.--Comparison of annual allowable cut using area and volume regulation



The volume harvested under area regulation would be greater than that harvested from the same forest by volume regulation for each of the first 50 years. After 50 years, annual harvest would continually drop until the 100th year when the cut would be only 68 percent of the volume produced under a volume regulation system. Again, this comes about because it is assumed that the oldest stands are cut first in both systems, and there is a concentration of volume in old growth. Therefore, if an equal area were to be cut, the volume cut would start higher than under volume regulation and decline as younger stands were reached.

Managers with little concern for fluctuations in annual cut would probably choose area over volume regulation since the forest will become fully regulated after one rotation. For other managers, the choice of a regulatory system is determined, to a large extent, by the progress made in the management unit (e.g., the working circle on the National Forests) toward an even distribution of acreage among rotation age and younger age classes.

If a firm is interested in an even flow of timber during an entire rotation period, volume regulation is likely to be more attractive than area regulation. However, if the distribution of area among age classes is more even, and not concentrated in over-rotation-age timber, then the transition from old-growth to second-growth stands is less abrupt and area regulation may be more attractive.

AVAILABILITY OF THE AREA COMPUTER PROGRAM

Requests for the "User's Manual for AREA Computer Program" (including source program listing) and FORTRAN IV source deck may be addressed to the Director, Pacific Northwest Forest and Range Experiment Station, U.S. Forest Service, P.O. Box 3141, Portland, Oregon 97208.

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DEBRIS AVALANCHING IN THIN SOILS DERIVED FROM BEDROCK

by

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INTRODUCTION

In southeast Alaska, many valley slopes that are greatly oversteepened by glacial erosion support mature forests rooted in shallow soil over bedrock. Debris avalanches on these slopes are one of the most frequent types of mass wastage in the region. They are especially common along the mainland and interior islands of the Alexander Archipelago where glacial till deposits are often thin or absent due to the resistance of local bedrock to glacial erosion.

At present, the forest land manager does not consider large-scale debris avalanching of this type an important erosion hazard in existing sale areas. Because of the poorer quality of timber on these soils and the steep and difficult terrain, slopes with shallow soils are often excluded from logging. As the logging industry expands to these sites in southeast Alaska, however, an understanding of this type of debris avalanching will become important in land management.

FIELD METHODS

During the summers of 1964 and 1965, reconnaissance investigations were made of debris avalanches in shallow soil. The study sites were chosen according to frequency of landslide occurrence and ease of access. The main site criterion was that glacial till be absent at the point of slide initiation. At each location, configuration of the slide trace and bedrock type and attitude were determined, and the angle of slope at the point of slide initiation was measured. Also at each locality, the soil depth was measured, and a probable cause of initial sliding was determined by reconstruction of events that apparently occurred when the slope failed.

SITE CHARACTERISTICS

The location and measured characteristics of each investigated site are shown in figure 1 and table 1.



Figure 1.--Map of southeast Alaska showing study site locations.

Table 1.--Measured study site characteristics and probable causes of sliding

Location	Aspect	Slope at head of slide	Debris deposit area	Bedrock type	Strike and dip	Soil thickness	Circumstances of slides
A. North end of Douglas Island	NE.	≈40°	Very small; slide did not reach bottom of slope	Interbedded gray-wacke and gray shale	N. 38° W., 30° NE.	≈3 feet	Slide occurred on lower edge of Treadwell ditch; failure of outer ditch wall
B. Young Bay--in drainage of East and West Creeks	N.	32°-40°	Very small; confined to alluvial flat at mouth of creek	Graywacke and black slate interbedded	N. 35° W., 45° NE.	1-3 feet	Small slides occur on extremely steep side slopes of both creeks by gravity sliding
C. Walter Island Arm	SW.	≈45°	Very small; ≈10 percent of total slide area ponded on the beach	Schist and schistose conglomerate	N. 60° W., 58° NE.; in-dipping bedrock smoothed by glacial scour	≈3 feet	Extremely steep to vertical bluffs overhanging head of slide
D. 1/2 mile east of Steamboat Bay near Cape Fanshaw	W.	≈40°	Not discernible in heavy undergrowth at slope base	Black argillite	N. 60° W., 78° NE.; in-dipping bedrock smoothed by glacial scour	≈3 feet	Extremely steep slope at slide head, with many indications of windthrow in area
E. Blind River, 12 miles south of Petersburg	NE.	35°-40°	Small; less than 10 percent of total slide area; debris ponded principally on or directly below logging road	Black argillite and graywacke interbedded. Overlain by thin patches of glacial till	N. 40° W., 60° NE.; bedrock surface smoothed by glacial scour	≈2 feet	Slides developed as slip-outs in shallow but steep-faced till banks along narrow stream channel in slope
F. Blake Channel Narrows	NE.	≈50°	Very small; most debris ponded at base of slope near beach	Schist	N. 45° W., 80° NE.	≈2 feet	Slide developed approximately half way up small creek as result of slip-out in thin soil covering a very steep pitch in slope
G. Blake Channel	W. (Slope dip controlled by jointing)	50°-60°	Very small; much of debris carried into channel	Quartz-diorite gneiss	Bedrock rounded and smoothed by glacial scour. Dominant joint set: N. 40° W., 30° NE. and N. 10° E., 70° NW.	2-3 feet	Extremely steep to vertical bluffs overhanging head of slide, apparently initiated by rockfall
H. Martin Creek Valley	E. (Slope dip controlled by jointing)	36°	Very small; debris ponded at base of slope, some emptied into Clay Lake	Quartz-diorite gneiss	Bedrock rounded and smoothed by glacial scour. Dominant joint set: N. 40° W., 30° NE.; N. 10° E., 70° NW.	2-3 feet	Principal jointing surface parallel to or slightly less than slope angle at head of slide; appears to have been an outward movement of blocks of bedrock along joint plane coupled with windthrow
I. Burnett Inlet	W.	40°	Very small; ponded in creek valley	Massive interbedded graywacke and black slate	N. 80° E., 38° SE.	Variable, but less than 3 feet	Bluffs overhanging head of slide, apparently initiated by rockfall
J. Neets Bay	N. and S.	40°-60°	Many individual slides; generally small; majority of slides ending in bay	Interbedded schist, black argillite, and graywacke	Variable, but predominantly NW. with dip SW.	Variable, but less than 3 feet	Extremely steep slope at slide head, some bluffs and rock cliffs indicating initiation by rockfall or slip-out of bedrock units; windthrow common; perhaps some destruction of root stabilization by logging
K. Gedney Pass	N.	40°-50°	Numerous slides; small; generally ending in the water	Biotite, schist, granite, diorite, gneiss	N. 70° W., 25° NE.	Variable, but less than 3 feet	Extremely steep slope at head of slides with overhanging bluffs
L. Walker Cove	N.	35°	Small; slide ending at water line	Granite, gneiss	(1/)	Less than 2 feet	Extremely steep side walls of stream channel; slide apparently caused by slip-out of lithosols from these side walls
M. Rudyerd Bay	N.	35°	Small; ending at water line	Granite, gneiss	(1/)	(1/)	Extremely steep slope with overhanging cliffs
N. Hollis, Prince of Wales Island	S.	40° (Begins above zone of till deposition)	Small; ponding in valley bottom before reaching creek	Interbedded black argillite and graywacke	N. 35° W., 36° SW.	(1/)	Extremely steep slope near head of slide with evidence of windthrow
O. Thorne River Valley, Prince of Wales Island	SW.	38° (Occurs in zone of no till deposition)	Small; ponded on logging road	Granite, gneiss	(1/)	≈3 feet	Very steep slope in logged area
P. Luck Lake, Prince of Wales Island	W.	40° (Occurs in area of no till deposition)	Small; ponded on creek bottom	Granodiorite	(1/)	≈2 feet	Steep slope with overhanging bluffs

1/ Data not available.

In every case, the slopes on which these slides occurred are extremely steep, lying between 35° and 40° or more, and support an old-growth forest of Sitka spruce and western hemlock rooted in a thin, rocky soil (figs. 2 and 3).



Figure 2.--View of a debris avalanche path. The timber is growing on a thin soil overlying metamorphosed graywacke. Note the broken nature of the bedrock surface indicative of frost wedging and the prying action of growing roots.



Figure 3.--A debris avalanche path in a thin soil. The bedrock is a glacially rounded, metamorphosed granite jointed parallel and perpendicular to the slope.

The soils are coarse and permeable with a high proportion of angular rock fragments and overlain by a thin organic mat consisting of intertwining roots and forest litter. The soils appear to drain very rapidly since overland flow was never observed, even during intense rainfall.

Bedrock slopes on which these soils have developed are smoothed off and dip into the valley at angles that approach or exceed the angle of internal friction for these soil materials^{1/} (fig. 3). This angle has been arbitrarily set, based on practical engineering experience, between 34° and 46° depending on density of the soils and weight of the overlying materials.^{2/} When the slope approaches or exceeds the angle of internal friction, the soil and slope conditions are such that downslope movement under the force of gravity is imminent.

DISCUSSION

Since these soils remain in position on the slopes and support extensive forest cover, a considerable resistance to downslope movement or "shearing" along the bedrock surface must exist. This shear resistance is additional to any internal friction between the individual soil particles and between the particles and the bedrock surface. The additional shear resistance is believed to be produced by the anchoring effect of root growth through the thin soil and into joints and fractures in the bedrock and, to a limited extent, by adhesion between individual particles due to soil water films.

Saturation and subsequent free water movement through the soil effectively reduce shear resistance due to adhesion and internal friction. The increased weight of the water-saturated soil and overlying organic mat increases the effective gravitational force acting to pull the soil downslope. Simultaneously, the buoyancy of the vertical component of free water movement tends to reduce the frictional resistance and adhesion between particles and along the bedrock surface. Rapid rise in piezometric level in glacial till soils during heavy rainfall periods

1/

The angle of internal friction is defined as the angle at which the driving forces due to gravity in a soil mass are equal and opposite to the resisting forces due to friction.

2/

Terzaghi, Karl, and Peck, R. B. Soil mechanics in engineering practice. 566 pp. New York: John Wiley and Sons, Inc. 1948.

is known to occur and is believed to be a principal force in a debris avalanche on till-covered slopes.^{3/ 4/} In shallow-to-bedrock soils, such rapid piezometric level rise has not yet been observed; however, it is probable that similar relationships also hold true, although the total effect may be somewhat less because of the coarse nature of the soil and resultant extremely rapid drainage of infiltrating water.

The decrease in shearing resistance of shallow soils is thought to be substantially aided by a decrease in root anchoring as the forest cover matures and the rate of root growth diminishes. The growing roots, which initially serve to anchor the soils on the slope, may actually counteract their early stabilizing effect by wedging out pieces and blocks of bedrock and loosening the underlying bedrock surface. The prying action of freezing water in the resultant root cracks probably adds considerably to this effect. Soil development adds to the proportion of greasy colloidal organic and iron compounds in the soil material over time, also adding to instability.

Slopes thus prepared are primed for sliding. During periods of maximum rainfall, only a small triggering force is necessary to cause the rapid downslope movement of a soil mass. Such a force may be produced by a sharp increase in soil water content or by a rapid increase in the weight of the soil mass. Field evidence suggests that the latter, due to tree blowdowns or the addition of rock masses resulting from gravity fall, is the principal initiating cause of these sliding phenomena. The majority of debris avalanches investigated occurred on timbered slopes and originated in areas of windthrown trees or extensive overhanging rock bluffs. A few showed indications that large blocks of bedrock had moved outward along zones of weakness at the upper slide margins with no indications of windthrow or rock fall. The triggering force here probably was excess hydrostatic pressure produced in joint cracks underlying the blocks.

In Neets Bay and Gedney Pass, where slopes of the type considered above have been logged, the initiating mechanisms are the same as those described earlier. The marked increase in sliding within the clearcut areas, first reported by Bishop and Stevens,^{5/} may be the result of progressive deterioration, after logging, of the root systems anchoring the shallow soil on the slopes.

^{3/} Bishop, D., and Stevens, M. E. Landslides on logged areas in southeast Alaska. U.S. Forest Serv. Res. Pap. NOR-1, 18 pp. 1964.

^{4/} Swanston, Douglas N. Soil-water piezometry in a southeast Alaska landslide area. (In preparation for publication, Pacific Northwest Forest & Range Exp. Sta., U.S. Forest Serv., Portland, Oreg.)

^{5/} See footnote 3.

CONCLUSIONS

On slopes steeper than the internal angle of friction and in the absence of a well-developed, cohesive soil, landslides must be considered a natural erosion process responding to the basic laws of physics. They are an inevitable result of any occurrence which tends to reduce the resistance of a slope to sliding.

Many of these slopes remain stable for years despite the action of external forces tending to reduce their resistance to sliding. The slope soils, therefore, must possess a slide resistance which is not directly related to the physical properties of the soil. Present indications are that this force is produced by tree rooting through the soil and into cracks in the underlying bedrock. Destruction of this rooting system would greatly increase susceptibility of the slope soil to slides.

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PNW-65

CLEMSON UNIVERSITY
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October 1967

INCREASES IN MAXIMUM STREAM TEMPERATURES After Logging in Old-Growth Douglas-Fir Watersheds

by Al Levno, *Forestry Research Technician*
and Jack Rothacher, *Project Leader*

Water temperature, one of the important factors of water quality, is strongly influenced by solar radiation reaching the stream and its channel. To determine the water temperature changes that occur when old-growth Douglas-fir forests are logged, maximum and minimum thermometers were installed in three streams on the H. J. Andrews Experimental Forest near Blue River, and records were maintained from 1959 through 1966.

The three small (237-, 150-, and 250-acre) northwest-sloping watersheds under study are located on the west side of the Cascade Range at an elevation of 1,500 to 3,500 feet (fig. 1). Climate is maritime with cool, dry summers and mild, wet winters. Average annual temperature is approximately 49° F., with a January average of 35° and a July average of 69° F. Snow is usually short-lived at these elevations. Topography is steep, and vegetation is predominately dense old-growth Douglas-fir with a relatively sparse understory. Each watershed contains about 10,000 feet of live stream with flow variations from 0.025 cubic foot per second during summer lows up to 60 cubic feet per second during winter storms.

THE STUDY

Weekly maximum and minimum water temperatures were recorded at the gaging stations on the three watersheds from 1959 through 1966. The period from 1959 to 1962 represents before-logging conditions. Watershed 2, which remained undisturbed through this period, served as a

Figure 2.--The streams under old-growth Douglas-fir forests receive only diffuse radiation through the forest and streamside vegetation.



Beginning in 1962, the following changes took place on the other two experimental watersheds:

1. One hundred percent clearcut. The entire 237-acre drainage of watershed 1 was logged by the skyline system during the 4-year period from August 1962 to July 1966. This report was completed before the creek had been cleaned and the slash burned (fig. 3).

Figure 3.--Watershed 1 stream channel after logging was completed (period 5). Logging debris partially shades the creek from heating by the sun



2. Twenty-five percent clearcut. Logging in watershed 3 was typical of the patch cutting system of timber harvesting in the Douglas-fir region. In 1959, right-of-way for 1.65 miles of road cleared 8 percent of the drainage. High-lead logging of three clearcut units during the winter of 1962-63 cleared another 25 percent of the drainage. In conjunction with logging, cull logs were cleared from approximately 1,300 feet of the stream channel which flows through the lower unit. The stream was shaded by smaller debris, and some vegetation remained in and adjacent to the channel. Slash burning followed in September 1963.
3. Stream scour after clearcutting. During the 1964 flood,^{1/} most of the main stream channels in watershed 3 were scoured to bedrock (fig. 1). The 1,300 feet of stream in the lower unit was directly exposed to the sun's radiation (fig. 4).



Figure 4.--Scoured section of stream channel in the lower clearcut unit of watershed 3. This section of stream channel is exposed to direct radiation from the sun (periods 3 and 4).

^{1/} Fredriksen, R. L. Christmas storm damage on the H. J. Andrews Experimental Forest. Pacific Northwest Forest & Range Exp. Sta. U.S. Forest Serv. Res. Note PNW-29, 11 pp., illus. 1965.

Water temperature was measured with "U" tube maximum-minimum thermometers,^{2/} submerged in the stream near the gaging station on each watershed. The thermometers were checked with a standard mercury thermometer at the time of each weekly reading. Although the registering thermometers are graduated in 2° increments, all temperatures were interpolated to the nearest degree.

Linear regressions based on weekly maximum and minimum water temperatures were calculated to express the relationship of watershed 1 (skyline logging) to watershed 2 (undisturbed) during five periods representing a range in cover conditions on watershed 1 from none to 100 percent logged:

	<u>Watershed 1</u>	<u>Stream exposure to solar radiation</u>
Period:		
1	Before logging; old-growth Douglas-fir with crown density of over 90 percent	All 7,000 feet of main stream channels shaded by timber
2	0 to 40 percent of timber felled; 0 to 30 percent logged ^{1/}	Timber felled along 3,000 feet; logged along 1,000 feet, south side only; logged along 300 feet, both sides
3	40 to 65 percent of timber felled; 30 to 55 percent logged	Timber felled along 7,000 feet; logged along 3,700 feet, south side only; logged along 1,300 feet, both sides
4	65 to 100 percent of timber felled; 55 to 90 percent logged	Timber felled along 7,000 feet; logged along 1,000 feet, south side only; logged along 6,000 feet, both sides
5	90 to 100 percent logged	Logged along 7,000 feet, both sides

^{1/} Timber was felled considerably in advance of logging. In general, felled timber provided more shade to soil and water surfaces before logging than after logs had been yarded.

^{2/} Taylor No. 5458.

Similar regressions were calculated for watersheds 3 and 2, representing four periods of stream exposure on watershed 3:

	<u>Watershed 3</u>	<u>Stream exposure to solar radiation</u>
Period:		
1	Before logging; road crosses stream channel in two places	Direct exposure negligible
2	25 percent logged (2,600 feet logged and burned out of a total stream channel of 9,000 feet)	Partial (29 percent of channel)
3	25 percent logged; stream scoured by 1964 flood	1st year after scouring, 1,300 feet (14 percent) of main stream directly exposed; 1,300 feet partially exposed
4	25 percent logged	2d year after scouring; same exposure as for period 3

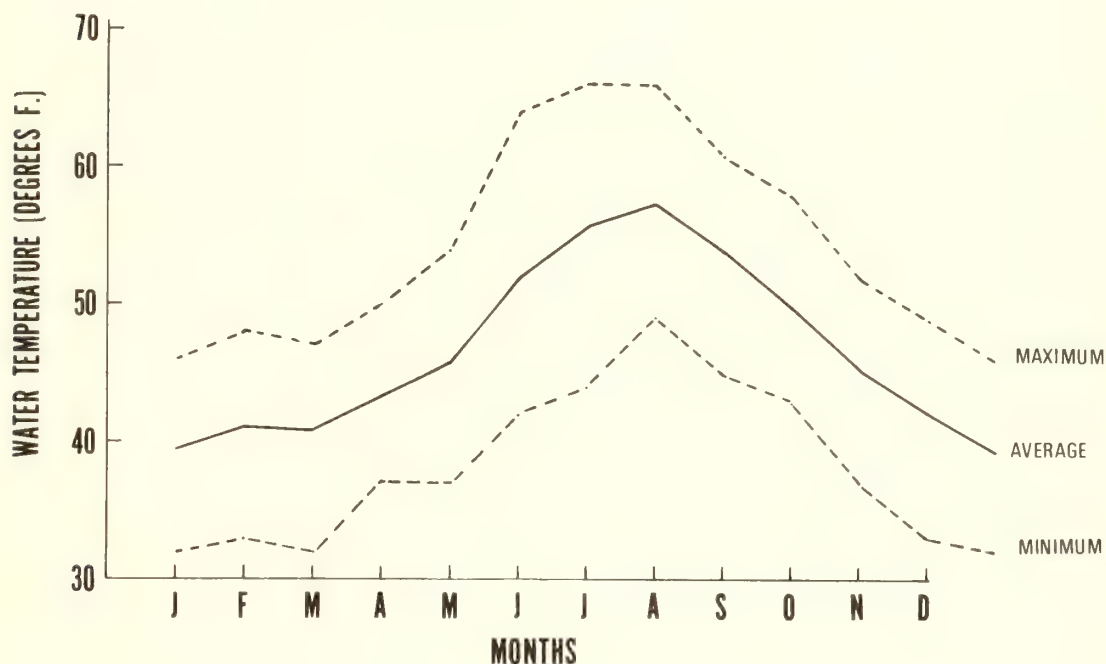
RESULTS

Direct solar radiation and convection are the principal processes influencing water temperatures. Under a dense forest cover, sunlight reaching the stream channel is largely diffuse and intermittent, and changes in water temperature vary primarily with air temperature by convection. When the forest cover is removed, direct solar radiation provides a large part of the energy required to raise water temperature.

Water temperature fluctuations at the lower end of these small watersheds reflect climatic events during the year (fig. 5). Minimum temperatures drop as low as 32° F. during extended cold spells in mid-winter but may rise rapidly during rainstorms associated with warm fronts from the Pacific Ocean. Maximum water temperatures occur during the months of July and August when air temperature is high, solar radiation is intense, streamflow is low, and water movement is slowed considerably. The slowly moving stream with numerous shallow pools has more time to absorb heat by convection under timber cover and by direct radiation from the sun where the cover has been removed. Maximum water temperature recorded at the gaging station on the undisturbed watershed during the years of study was 66° F. Water temperature records of springs near the headwaters of both watersheds 2 and 3 show that ground

water varied only from 43° to 45° F. throughout each of several years. Direct sunlight reaches the stream in only a few areas under undisturbed forests, indicating that surface water may warm up 20° F. or more, primarily by convection.

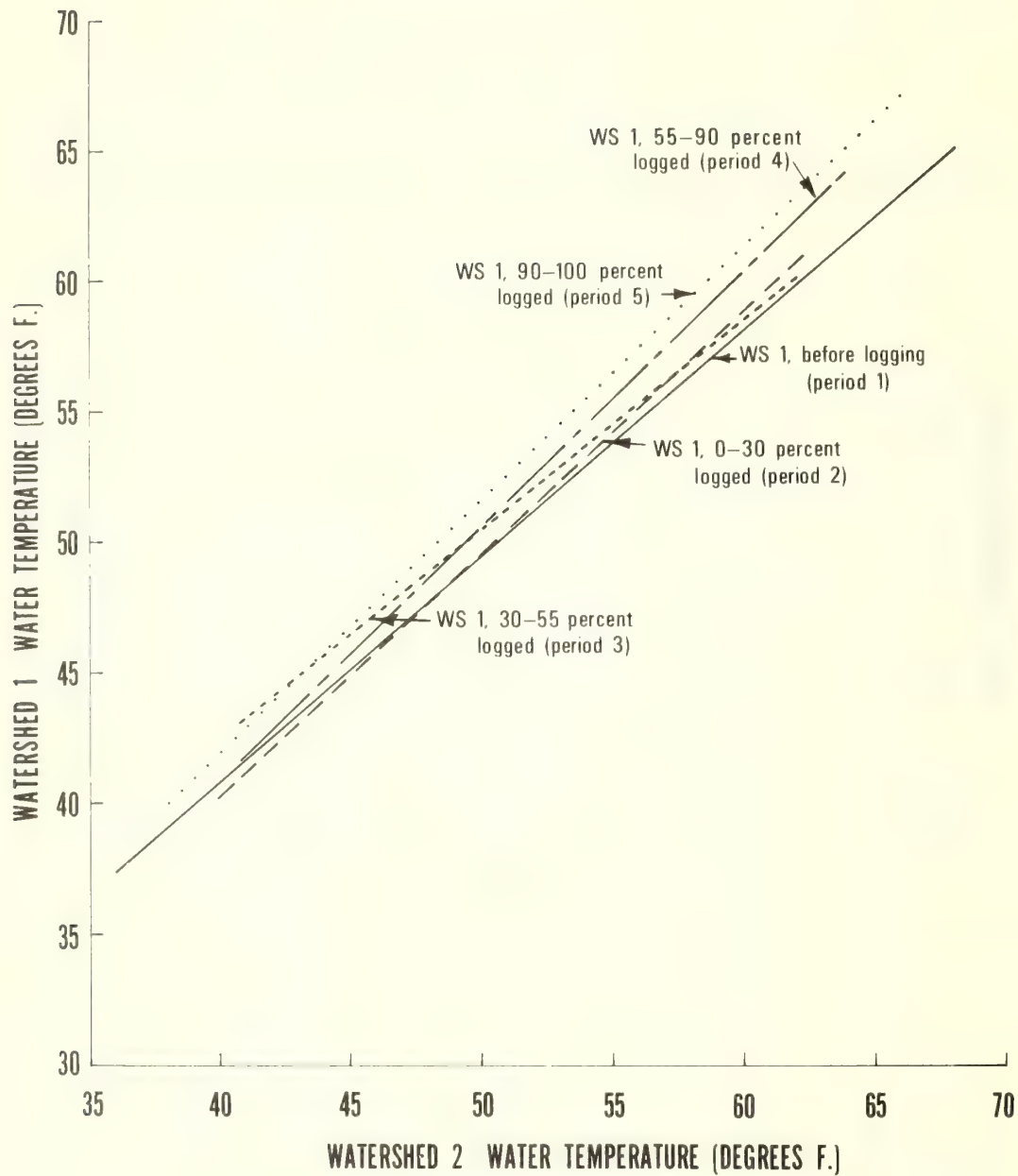
Figure 5.--Monthly water temperature, watershed 2; H. J. Andrews Experimental Forest, 1959-66.



In this study, no statistically significant change in the normal fluctuations of water temperature was found until drastic changes had been made in the vegetative cover along the stream channels.

The relationships of maximum weekly water temperatures recorded on watersheds 1 and 2 are shown in figure 6. Each line represents one of the five periods from none to 100 percent logged on watershed 1. Watershed 2 remained undisturbed through all periods. The standard error of the regressions was less than 2° F. in all periods.

Figure 6.--Maximum weekly water temperature, watersheds 1 and 2.



The relationships for periods 1, 2, and 3 are not statistically different; i.e., there was no statistical evidence for a difference in maximum temperatures when less than 55 percent of the drainage was logged. Both periods 4 and 5 were statistically different from period 1

(before logging), indicating that when a major portion of watershed 1 was cleared there was a measurable increase in maximum water temperatures. After 100 percent of the drainage had been logged (period 5), but before burning and stream cleaning, the average of July and August weekly maximums measured on watershed 1 was 62° F. This was 4° higher than the predicted average of 58° F. had the area remained unlogged and the relationship of period 1 remained unchanged.

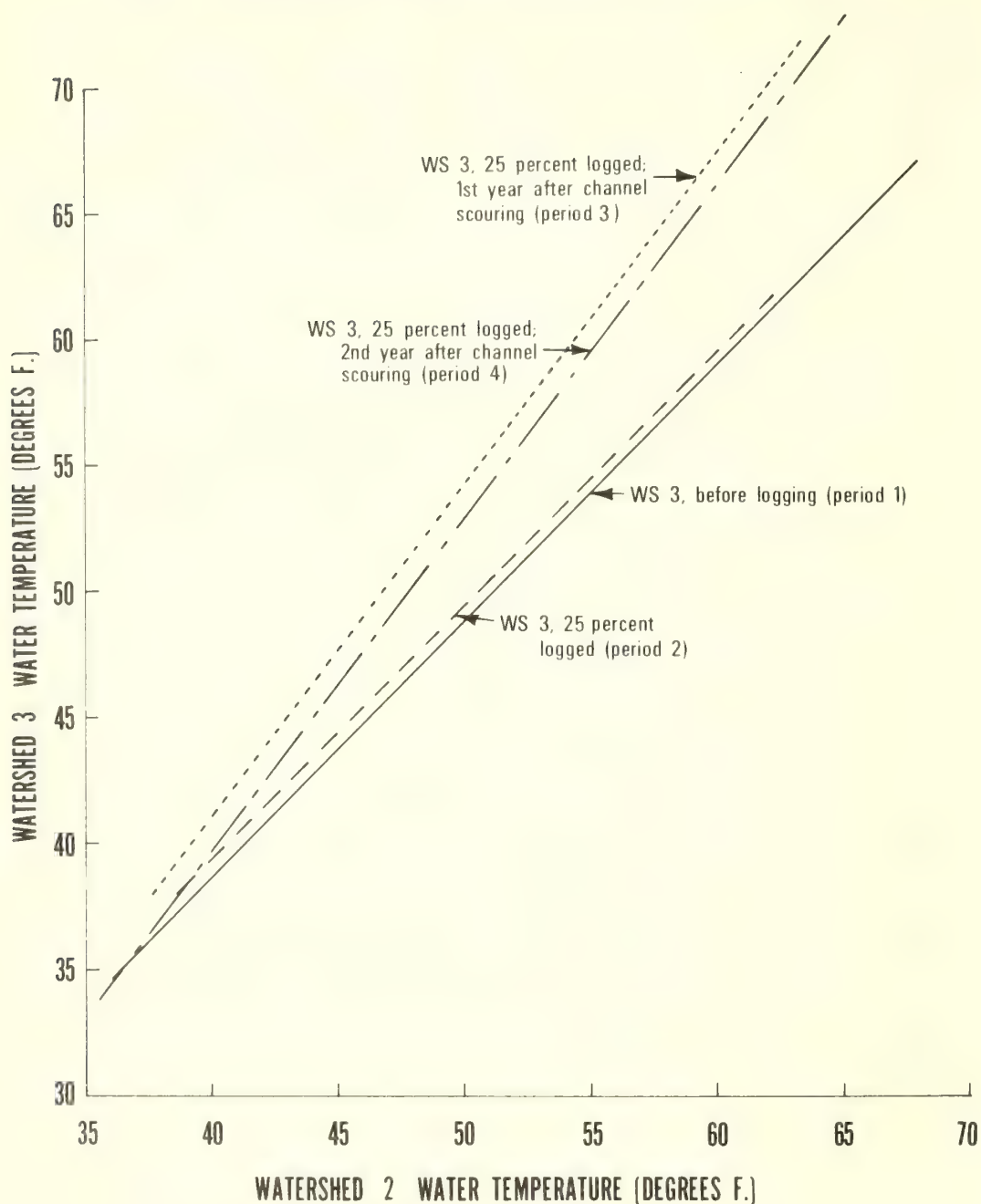
As expected from results in watershed 1, logging and burning of 25 percent of the area in watershed 3, plus removal of cull logs from the stream channel, showed no statistical evidence of a change in maximum water temperatures (fig. 7, periods 1 and 2). However, highly significant increases in maximums were recorded the year after the stream had been scoured by the 1964 flood (period 3). Since little cover developed in the scoured streambed during the first year, it was not surprising to find that maximums recorded during the second year after the storm (period 4) still showed highly significant increases over the prelogged and logged years.

Maximum temperatures were not only higher in the scoured channel, but water temperature responded much more rapidly to changing climatic factors. The standard error of the regression was less than 2° F. until after stream scouring when it rose to 3.5° F. The added variation may be principally due to the difference in the manner of heating--convection in watershed 2; radiation in watershed 3.

At the scoured section of the streams in the lower unit of watershed 3, Brown, working with energy budget techniques to predict water temperature,^{3/} found increases of as much as 16° F. from the time the stream entered the clearcut at the upper edge of the unit until it left the area at the lower end, a distance of 1,300 feet exposed to direct solar radiation. On June 14, 1966, he recorded a maximum of 77° F. Further downstream, after the stream had passed through 700 feet of undisturbed canopy, maximum water temperature at the stream gaging station was 69° F., indicating considerable cooling in the forest-shaded stretch. Although a continuous record is not available for the lower end of the scoured stream section, a maximum water temperature of 71° F. at the gaging station would suggest that the instantaneous maximum might have approached 80° F. in the clearcut.

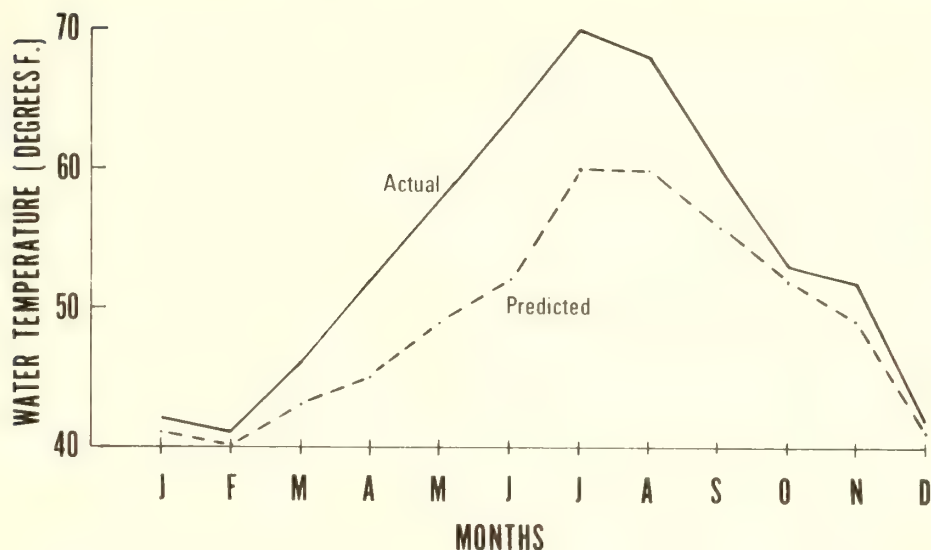
^{3/} Brown, George Wallace III. Temperature prediction using energy budget techniques on small mountain streams. 1967. (Unpublished Ph. D. thesis on file at Oreg. State Univ., Corvallis.)

Figure 7.--Maximum weekly water temperature, watersheds 3 and 2.



The influence of season of the year on the increase in maximum water temperature is illustrated in figure 8, which compares measured temperatures from watershed 3 after exposure of the streambed by

Figure 8.--Estimated and measured mean monthly maximum water temperatures, watershed 3, 1965.



scouring with the predicted temperature had the watershed remained undisturbed and the relationship of period 1 remained unchanged. After stream scouring, mean monthly maximum temperatures at the gaging station reached 70° F. in July 1965 compared with an estimated maximum of 60° F. with a timber cover. Increases of 7° to 12° F. persisted from April through August.

As can be seen in figure 8, changes in winter maximum water temperatures are small. This is also shown by the convergence of the regression lines at lower temperatures in figures 6 and 7. Regressions of weekly minimum temperatures (not presented) showed no consistent relationship with progress of logging or the change in exposure following scouring of the channel by slide debris. There are apparently several interacting climatic factors, not recorded, which influence minimum temperatures whereas solar insolation is the predominant factor influencing maximum water temperatures.

SUMMARY

Under the pattern of patch clearcuts commonly used in the Douglas-fir region, little or no increase in maximum stream temperatures would be expected unless a large proportion of the streambed was directly

exposed to solar radiation. Protection of any streamside vegetation which provides some shade to the stream will apparently help prevent excessive increases in maximum water temperatures.

On a northwest-facing slope, extensive logging on a forested watershed increased maximum water temperature only after 55 percent of the drainage was logged and timber had been felled along all the major stream channels. On south-facing slopes, an increase might be noted with a smaller percentage of cutting. Maximum water temperatures may also increase as a result of drastic exposure of a section of stream-bed, such as occurs following scouring by flood waters, burning, channel changes, excessive stream cleaning, etc. Some cooling also takes place when the stream again passes through a forest-shaded stretch. In this study, mean monthly temperature increases of 7° to 12° F. persisted from April through August, following direct exposure of the stream channel by scouring during the 1964 flood. Recent developments in techniques for temperature prediction using an energy budget approach may soon permit us to estimate the effects of several factors of stream exposure on maximum water temperature.

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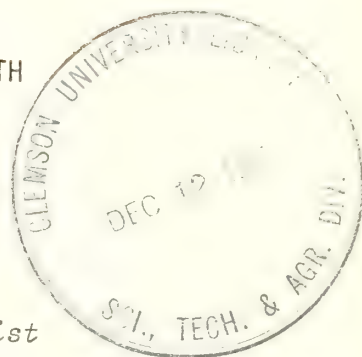
PNW-66

October 1967

EFFECT OF pH AND TEMPERATURE ON GROWTH OF *PORIA WEIRII* IN VITRO^{1/}

by

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J. M. Trappe, *Principal Mycologist*
W. B. Bollen, *Principal Microbiologist*



Our studies on the possible role of *Alnus rubra* Bong. in biological control of *Poria weirii* Murr., a destructive pathogen of conifer roots in western North America, have occasionally been thwarted by physiological inactivity of the fungus under certain laboratory conditions. Suspecting either temperature or pH of the medium to be limiting and not finding literature an optima for *P. weirii*, we conducted the studies reported here using the single isolate with which we were concerned.

^{1/} Research was supported in part by National Science Foundation Grant No. GB-3214.

^{2/} Department of Microbiology, Oregon State University, Corvallis, Oreg.

The liquid medium developed by Trione (6)^{3/} was used, except that 10 g. of glucose per liter was substituted for 20 g. of sucrose. The chemical compositions of the medium were as follows:

KH ₂ PO ₄	613	mg.
MgSO ₄ · 7 H ₂ O	246	mg.
K ₂ HPO ₄ · 3 H ₂ O	114	mg.
CaCl ₂	55.5	mg.
Sodium ferric diethylene- triaminepentaacetate	20	mg.
ZnSO ₄ · 7 H ₂ O	3.52	mg.
CuSO ₄ · 5 H ₂ O	0.38	mg.
Na ₂ MoO ₄ · 2 H ₂ O	0.025	mg.
Thiamine · HCl	5	mg.
L-asparagine	2	g.
Glucose	10	g.
Distilled water	1000	ml.

The medium was divided into twelve 200-ml. portions and the pH of each was adjusted with HCl or NaOH to provide series ranging from pH 3.0 to 7.5 at 0.5 intervals. After sterilization by filtration through an ultrafine porosity fritted disk, 50 ml. of medium at each pH were added aseptically to four replicate, sterile, 150-ml. Erlenmeyer flasks. A 4-mm. plug of inoculum, cut from a 7-day-old malt-agar culture of *P. weirii*, then was added. After incubation at 25° C. for 30 days, mycelia were harvested, freed of the agar inoculum plug, dried overnight at 110° C. and weighed.

For study of temperature effects, similar procedures were followed, except that the medium was adjusted to pH 6 and sterilized by autoclaving; five replicates were used at each temperature in the range of 5 to

^{3/} Italic numbers in parentheses refer to Literature Cited, p. 6.

35° C. at 5° intervals. As a quick check on temperature effects, five malt-agar plates inoculated with mycelial plugs were placed in each incubator along with the flasks of liquid medium. Colony diameters of these were measured 12 days after inoculation.

Statistical significance of relationships between final weights or diameters of colonies and treatments was tested by regression analysis. Though the need to use different incubators for temperature treatments precluded randomization, the possibility of extraneous factors affecting fungus growth in this kind of experiment is remote, so regression analysis can be assumed to be valid.

Mean dry weight of *P. weirii* increased with pH at an accelerating rate between pH 3.0 and 6.0 as determined by regression analysis of the data. The fall from maximum growth at pH 6.0 to no growth at pH 6.5 and above was abrupt (fig. 1). At time of harvest, the pH of each medium generally was higher than at the outset except for those starting at pH 5.5 or higher (table 1).

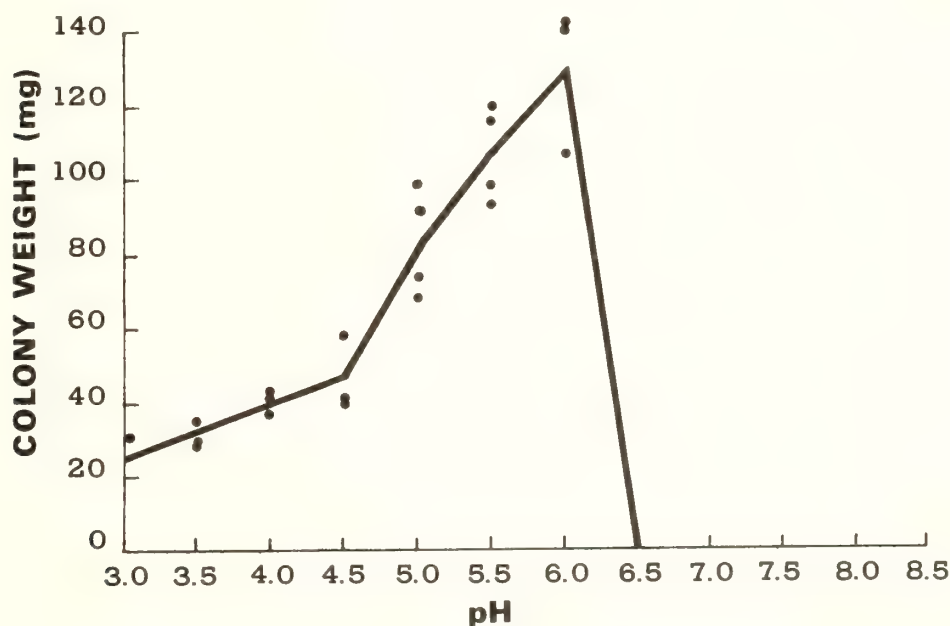


Figure 1.--Weights of colonies of *Poria weirii* grown for 30 days in media with different beginning pH values (four replicates at each pH).

Table 1.--Dry weight of mycelium of *Poria weirii* grown 30 days in synthetic medium with various H-ion concentrations

Initial pH	Mean colony weight (mg.)	Final pH
3.0	24	4.3
3.5	31	5.0
4.0	40	5.0
4.5	46	4.6
5.0	84	5.7
5.5	107	5.3
6.0	130	5.7
6.5	0	6.5
7.0	0	7.0
7.5	0	7.4

Mean dry weight of colonies of *P. weirii* at pH 6 increased with temperature from 5° C. to a maximum at 20° C., then fell off abruptly at temperatures above 20° C. to no growth at 30° C. or higher (fig. 2). The resulting complex curve proved highly significant as determined by regression analysis of the data. Similar trends in diameter growth on malt agar also were highly significant.

Having determined for this isolate of *P. weirii* that a pH of 6.0 and temperature 20° C. were optimal for the conditions of our research, we plan no further studies of this kind at present. Though the range of variation within this species remains to be defined, we can reasonably anticipate that isolates of *P. weirii* will vary from each other in pH and temperature optima for growth, as strains or geographical isolates of the same species may respond differently (1, 2, 3, 4, 5, 7).

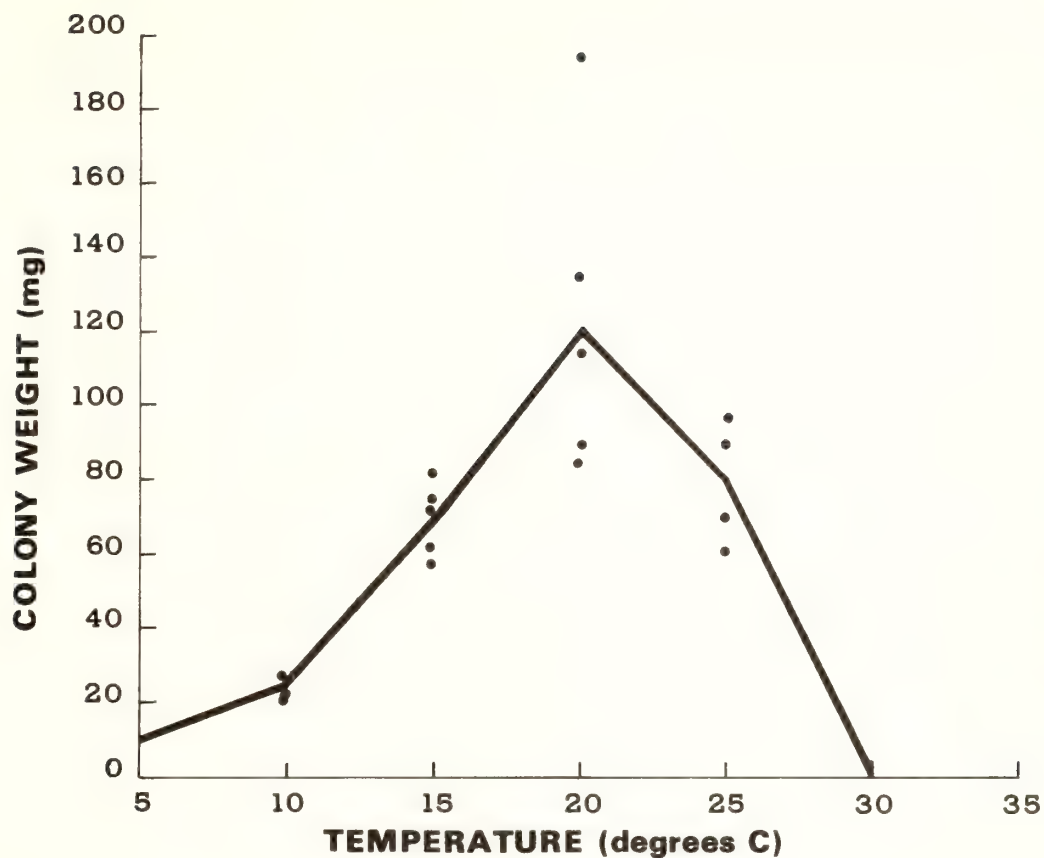


Figure 2.--Weights of colonies of *Poria weirii* grown for 30 days in synthetic medium at different temperatures (five replicates at each temperature).

LITERATURE CITED

- (1) Cowling, E. B., and Kelman, A.
1964. Influence of temperature growth of *Fomes annosus* isolates. *Phytopathology* 54: 373-378.
- (2) Edgington, L. V., and Walker, J. C.
1957. Influence of soil and air temperature on *Verticillium* wilt. *Phytopathology* 47: 594-598.
- (3) Etheridge, D. C.
1955. Comparative studies of North American and European cultures of the root rot fungus, *Fomes annosus* (Fr.) Cooke. *Can. J. Bot.* 33: 416-428.
- (4) Humphrey, C. J., and Siggers, P. V.
1933. Temperature relations of wood-destroying fungi. *J. Agr. Res.* 47: 997-1008.
- (5) Thom, C., and Raper, K. B.
1941. The *Aspergillus glaucus* group. U.S. Dep. Agr. Misc. Pub. 426: 1-46.
- (6) Trione, Edward J.
1964. Isolation and *in vitro* culture of the wheat bunt fungi *Tilletia caries* and *T. controversa*. *Phytopathology* 54: 592-596.
- (7) Weimer, J. L., and Harter, L. L. ~
1923. Temperature relations of eleven species of *Rhizopus*. *J. Agr. Res.* 24: 1-40.

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Research Note

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PNW-67

October 1967

NEW TOOLS AND METHODS IN FOREST MENSURATION^{1/}

by David Bruce
Principal Mensurationist

Since the general theme of the 1966 symposium is "Measuring the Southern Forest," I expect many of the other participants to describe new methods, and a few of them to mention new tools. I hope they do, because it is difficult to find much that is really new in forest mensuration. However, before preparing my contribution, I tried to identify some new things that would not be better covered by other speakers.

To find these things, I conducted an informal mail survey of selected foresters in the South, describing my subject and asking for suggestions about a few important new tools and methods in mensuration. This was a most successful survey. I received an 83-percent response and, without too much finagling with the results, found that each of the same three categories was mentioned by 80 percent of the respondents. Each of another three categories received 20 percent of the votes.

The three important categories of new tools and methods in forest mensuration were: (1) instruments for measuring upper stems

^{1/} As published in Measuring the Southern Forest, Thomas D. Keister, ed., Louisiana State Univ. 15th Annu. Forest. Symp. Proc. 1966: 83-92.

of standing trees; (2) three-P sampling or other statistically designed cruising methods; (3) use of digital computers or automatic data processing.

These three categories may overlap what other speakers are covering. However, the list of topics showed that no one else was assigned instruments as a specific subject. I checked with Al Bickford to see what he planned to say about "Sampling Methods," and with George Furnival to see what he was going to cover under "Computer Applications." Neither of them had in mind the same aspects of these subjects that I want to describe, so I was quite happy with the outcome of my survey.

Instruments for Measuring Upper Stems of Standing Trees

Most of these instruments can measure upper stem diameters from a distance. This suggests a strong concern with the measurement of trees before they are scheduled for felling. This, in turn, implies a recognized need for better presale volume or value estimates, improved inventories of stands not scheduled for early felling, or for repeated measurements of trees or stands from which accurate estimates of growth can be made.

The capabilities of the instruments vary. Unfortunately, and almost predictably, the most accurate is the most expensive. However, I feel that the expressed need for such instruments will eventually lead to the development of new devices. These won't be as expensive as the highest cost ones today--but don't expect to buy a good one in a dime store.

These instruments measure in the field the actual dimensions of all parts of each sample stem. This allows direct estimates of volume in each of several value or product classes. These direct estimates avoid the bias of volume tables prepared by measurement of trees that are often not representative of the stand being measured. Furthermore, volume tables seldom permit breakdown into value or product class.

The most accurate instrument for measuring upper stems that I have used is the Barr & Stroud rangefinder dendrometer. Last fall, five of us at the Pacific Northwest Experiment Station tested its accuracy. For eight trees 15 to 26 inches in diameter, at distances of 66 to 144 feet, the average coefficient of variation (CV) of diameter was 0.88 percent. A single instrument setup was used for each tree and a small tag was put on the front of the tree to indicate point of measure-

ment. Each observer measured each tree twice. The CV includes observer, repetition, and tree interactions with these. On the same trees, the CV of extremely careful caliper measurements, taken in the same direction as the dendrometer readings, was 0.42 percent. The difference between the means of eighty dendrometer measurements and forty caliper measurements was 0.07 inch. The CV of basal area for the dendrometer, including difference between instruments, was 2.5 percent. Grosenbaugh (1963) reported 3.9 percent CV of basal area measurement on some pines at Crossett, but he included aspect as a variable, which would increase variation somewhat.

In our test, we got a CV of 0.90 percent for slope distance measurements against 0.18 percent for steel tape. The CV for dendrometer height determinations was 1.16 percent. This was not compared with other height measurements; however, this CV and that for basal area suggest that volume will be predicted within the 4 percent found by Grosenbaugh at Crossett.

In another test last summer, using the dendrometer in an eighty-year-old Douglas-fir, permanent sample plot, we measured seventeen trees. Excluding one tree with a broken top, we found that our standard volume table was overestimating the volume of small trees by 12 percent and underestimating the volume of big trees by 10 percent. (Tree diameters were from 11 inches to 24 inches.) For the tree with a broken top, direct measurement was much easier than using the volume table. This volume would be the total for a tree whose height included the fifty-foot (more or less) missing tip, with a deduction for the tip volume based on this guessed length and the estimated diameter at the break (13 inches).

A comparison of dendrometer-measured gross volumes of over a hundred trees with those based on the local volume tables actually used in one Oregon timber sales appraisal showed an overestimate of 9 percent for the volume tables.

These few examples are cited to indicate the gains in accuracy that may be expected when upper stems are measured. Instruments other than the Barr & Stroud dendrometer, mentioned by my respondents and others, include Wheeler's optical calipers, McClure's mirror caliper, Bitterlich's Spiegel-Relascope, and the Zeiss Teletop. I probably should add a couple: mil-scale binoculars and the Liljenstrom dendrometer. Some of these instruments aren't exactly new.

I do not have data from comparable tests showing the relative accuracy of all these different instruments. These tests are not

necessary to rank them in probable order of relative accuracy, since their operating principles can be used for this purpose.

For two reasons, instruments that displace the image of one side of a tree so that it can be aligned with the other side will be more accurate than those that require alignment of two reference marks with the two sides of the tree. The first reason is that there are only two lines to bring into coincidence instead of four. The second advantage for displaced images is that slight movement of the instrument, or the tree, will not interfere with alignment.

An instrument that adjusts the displaced image so that amount of adjustment can be read after the two images are brought into coincidence will be more accurate than one which needs to be read while the two sides of the tree are aligned.

Magnification will improve accuracy of alignment. However, the wrong telescope might do as much harm as good. Some defects that could be introduced through poor optical design are: too small a field of view, reduced illumination of image, and too small an exit pupil for optimum resolution of the image.

A telescopic instrument has an advantage other than magnification, if it is desired to use an internal scale to measure relative width of a tree--the reference marks and image of the tree are both in the focal plane of the eye lens. This does away with the nearly impossible job of clearly seeing a tree at a distance and reference marks close to the eye. Such a telescopic instrument must be mounted on a staff or tripod to eliminate instrument movement, but even so, movement of the tree by wind will reduce accuracy.

How then, would I rank these other instruments in order of probable accuracy? There are two parts to this: repeatability of measurements (or precision) and lack of bias. Precise instruments are not necessarily accurate because they may be biased.

First in rank would be Wheeler's telescopic optical calipers, which about equal the Barr & Stroud dendrometer in overall accuracy. First models of the telescopic calipers lacked a sharp separation of the two images. Despite this problem, repeated readings on the same point on a tree by different observers fell in a narrow range.

The Zeiss Teletop should be equally accurate for trees under 12 inches and not quite so accurate for trees 12 inches to 24 inches since two separate readings are required.

Wheeler's simple penta-prism calipers, which have been in use in the South for about three years, would probably rank next. The use of penta prisms practically eliminates bias. These calipers probably would be better than mil-scale binoculars for swaying upper stems but not so accurate for form class determinations, provided a tripod was used with the binoculars and a reticle with a suitable scale was substituted for the mil-scale.

I have not examined a Liljenstrom dendrometer, but I suppose it would be about as accurate as a modified binocular. These last two instruments require careful calibration and accurate determination of slope distance to eliminate bias.

McClure's mirror caliper should be a trifle less accurate than the prism calipers because the reading is made while the two sides of the tree are lined up and, also, any deviation from parallelism of the mirrors will introduce bias. The Spiegel-Relascope would rank next because it requires four-way alignment and accurate distance determinations.

These accuracy ratings do not necessarily rank the instruments in order of utility for practical field measurement. Further, the differences in accuracy may be relatively small. A test, similar to the one we made of the rangefinder dendrometer, would probably find a CV of diameter measurement of about 2 percent or a little more for the Spiegel-Relascope--although a recent article in *Malayan Forester* (Brunig, 1964) suggests a CV closer to 1 percent. However, the Spiegel-Relascope has the advantage of automatic slope correction and can also be used as a clinometer. These features make it a very useful field instrument.

I would expect CV's of 0.75 to 2.5 percent for most of these instruments in determining diameters. Some would have to be used at fairly short distances to stay in this range. Because of stem irregularities, telescopic instruments are not likely to demonstrate much greater accuracy than 0.75 percent, unless measurements are made on telephone poles or repeated measurements are made by people with exceptionally good memories. The easiest trees to measure accurately are probably those with smooth bark, and possibly the hardest are trees with large plates of bark. With Douglas-fir, plates of bark six to twelve inches long can stand out on the silhouette one-quarter to one-half inch. If the approximate level of measurement is at the top or bottom of one of these plates, large discrepancies in successive readings can occur.

Diameter measurement is only one part of upper stem measurement. The only new gadget for height measurement, mentioned by my respondents, was the fiber glass extension pole. I think this is significant, because I have yet to find a really good clinometer. Something like the Suunto, with a drum at least twice the size, a well-illuminated, easily read scale, and a better sighting arrangement should not be too expensive and would be an improvement over what is now available. The World War II Navy Position Angle Finder was such an instrument, but apparently is no longer manufactured.

Brendemuehl and Baker, 1965, of the Southern Station, recently described a sectional aluminum pole which they claimed was more convenient than the telescoping fiber glass pole. I can think of several advantages which were not mentioned. After we used the fiber glass pole in the rain, it took about a week to dry the inside of it. Also, in the rain, one of the top sections occasionally unlocked while the pole was being extended vertically--if not noticed, this could cause errors.

Three-P Sampling

All I want to say about sampling methods is to report briefly on the gain in accuracy found in one test of three-P sampling (Grosenbaugh, 1964), plus dendrometer measurements, in the Northwest (Johnson, et al.). "Three-P" means probability proportional to prediction, so three-P is a form of variable probability sampling. It is used in sales appraisals where an ocular estimate (prediction) can be made of each tree, not in inventories where only a small fraction of the population is examined. It is most efficient when the prediction is actually proportional to the variable of interest, whether the latter be dollars of stumpage or volume of wood. In effect, it is a kind of nearly continuous stratification, where each level of prediction is a stratum. The number of units in the sample and error of estimate can be estimated fairly closely, but number in the sample cannot be specified exactly in advance. Since the outcome of samplings can be a useful guide to design of other similar sampling, results of this Northwest trial may be useful to some of you

In a presale cruise of 1-1/2 million board feet of old-growth ponderosa pine, three-P sampling had a standard error of estimate of 4 percent against 9 percent for a standard one-in-twenty tree cruise. This is not a real measure of relative accuracy, since the standard errors measure different kinds of variation. The three-P error is based on the variation of the ratio of actual volume measured by the dendrometer to a local volume table estimate based on measured

diameter. This diameter measurement was substituted for volume estimates to get more uniformity than we could expect from ocular estimates of two markers. Thus, three-P error measures the deviation of measured from estimated volume and gives limits within which total volume would be expected to fall if all trees were measured.

In the one-in-twenty cruise, the 9-percent error of estimate is based on the variation of estimated volumes within the sample. These estimates were based on taped diameters, ocularly estimated number of logs, an average form class, and a volume table. The error of estimate includes no allowance for possible systematic bias in height or form class estimates, no consideration of possible differences in average upper-stem form of trees in the volume table and those on the sale area, and no measure of the variation in volume of the trees on which the volume table was based. Thus, the error of the standard cruise will give an estimate of the limits within which total volume would fall, if all trees had been estimated the same as sample trees.

One other difference between the two samplings was that there were thirty-six three-P sample trees and eighty-eight in the standard cruise. Of course, it took longer to measure the thirty-six trees than to tape diameters and eyeball heights on the eighty-eight trees. However, it would have required 336 trees by the standard cruise method to get an error of estimate as low as that for three-P.

Three-P gross volume estimate was 1,498,000 board feet and standard cruise estimate was 1,860,000 board feet. Gross scale for the sale was 1,508,000 board feet. Of course, scaling is not an accurate means of estimating volume; but its close correspondence to results of dendrometer measurements is encouraging and suggests doing away with the high cost of scaling.

Use of Digital Computers

The computer capability most familiar to research foresters is multiple regression analysis. It used to take many hours to fit by least squares a multiple regression involving four or more variables. Machine programs are available that will screen thirty or forty variables in stepwise or controlled deletion programs to find one or more combinations of the few independent variables that account for most of the variation in the dependent variable. Since few people measure this many variables, the thirty to forty or fewer usually consist of transformations or combinations of measured variables that seem

likely to be better related than untransformed measurements. These programs have been used in soil-site studies, in growth studies, and in other studies to identify transformations of measured variables in a sample with highest coefficient of determination and, hence, with good promise of being the most useful predictors

A similar computer capability is the production of kinds of multivariate analyses used in econometric and sociological studies. An early application in forestry was discriminant function analysis. However, more and more of these techniques are being applied to forestry data.

The usual least squares methods of fitting equations cannot be used for some of the more flexible growth curves. These require repeated fitting of equations with nonlinear coefficients which can be done quickly on a computer. The simple growth curves that can be fitted by usual least squares methods may have high coefficients of determination but may have no logical interpretation in terms of how trees really grow.

Some mensurationists are old-fashioned enough to want to see their data plotted. This is painless if you use an X-Y plotter. In fact, it's more accurate than hand plotting, and one can plot the dependent variable against all the independent variables, or plot the residuals against the variables in an equation or other variables. These plots quickly reveal correlation of residuals with independent variables and the possible need for weighting. They also can suggest untried functions of independent variables that will fit better than those already tried.

Computers with large memories can digest stem maps with trees located by X-Y coordinates and identified by variables of interest, such as diameter, height, volume, crown size, and growth rate. Such maps can be used in a number of different types of studies. These can be used to study the errors of systematic and other sampling designs, to model stand growth and development, to study effects of clumping and density on growth, and to study alternative intermediate cutting systems.

Tree growth can be simulated in other ways than by this stem mapping procedure. For example, a stand can be broken down into groups of trees that are expected to die or to be removed in intermediate cuts at different stages in stand history. Rules governing progressive changes in competition and growth rates among groups

can be developed empirically or theoretically. This model can then be used to predict probable stand growth and yield. Tests against actual stand remeasurements will demonstrate validity of the model.

Detailed tree measurement data from stands representative of sites and management practices on a large area can be placed on punch cards or on magnetic tape. These become a universal volume table. Whenever a question arises about the potential yield of the property for any product mix, a set of cutting rules can be drawn up specifying which parts of which size trees will go into each product. The stem measurement data are then used to get yields for trees of varying size and these, in turn, are applied to stand tables for the various sites and ages involved.

A new procedure for consistent volume table compilation is feasible. Equations describing average stem profiles and the changes in stem profile related to d.b.h., total height, crown height, and, possibly, other factors can be fitted to tree measurement data. These equations can be integrated between appropriate limits to get cubic volume to any desired top diameter, including or excluding the stump. These equations can also be used to produce taper tables showing for selected tree heights and diameters the d.i.b. at intervals of two feet plus a fraction of trim allowance above stump. Board-foot volume tables can be prepared by giving the machine scaling rules and board-foot equations or tables to apply to these taper tables.

This brief review far from exhausts the ways electronic computers can help in forest mensuration. However, I may have exhausted the patience of those readers not already introduced to analysis methods and computing techniques. Nevertheless, I would like to mention some current general changes in mensuration due to the use of computers.

I think this facility in computing encourages foresters to measure more variables in their site, growth, or other studies. Also, I believe there are more attempts to quantify factors formerly described in qualitative terms. A further quite evident trend is found in field forms, which are now designed for ease of transcription to punch card or tape. Also, there are systems for recording data on cards or tape in the field, most of which will require improvement in means of field editing to detect erroneous records before they become generally useful.

I believe there is a continuing change in regression analysis, from the use of functions that fit batches of data to a search for functions

that have biological meaning. Finally, I expect to see more and more different analysis techniques borrowed from econometrics, engineering, and the social sciences.

This look at what is new in tools and methods in forest measurement suggests that we are a long way from having the instruments we need. However, trials and tests of the few new ones demonstrate both the gains that can be expected when better instruments are available and the need for development of such instruments.

Electronic computers have opened new opportunities for mensuration and silviculture studies which will eventually produce explanations of the complicated processes controlling growth and yield in the forest. The practical outcome of all this will be the ability to forecast with greater certainty the yield of managed forests and to evaluate more precisely the economic feasibility of proposed cultural treatments.

LITERATURE CITED

- Brendemuehl, R. H., and James B. Baker. 1965. Sectional pole for measuring tree heights. South. For. Exp. Sta. U.S. For. Serv. Res. Note SO-20, 2 pp.
- Brunig, E. F. W. 1964. A preliminary field test of instruments measuring diameters of standing trees. Malayan Forest. 27(4): 361-369.
- Grosenbaugh, L. R. 1963. Optical dendrometers for out-of-reach diameters: A conspectus and some new theory. For. Sci. Monogr. 4, 47 pp., illus.
- _____. 1964. Some suggestions for better sample-tree measurement. Soc. Amer. Foresters Proc. 1963: 36-42.
- Johnson, F. A., W. G. Dahms, and P. E. Hightree. 1966. (In press, Pacific Northwest Forest & Range Exp. Sta., U.S. For. Serv., Portland, Ore.)

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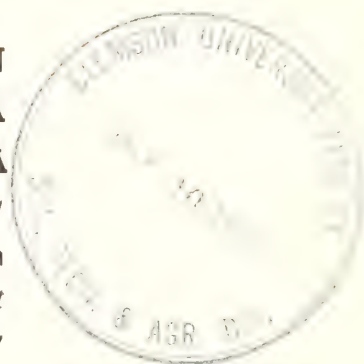
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SOIL-WATER PIEZOMETRY IN A SOUTHEAST ALASKA LANDSLIDE AREA

by

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INTRODUCTION

Soil-water piezometry started in the summer of 1964 and continued in 1965 as part of studies to determine debris avalanche causes. The measurements provide information on development and distribution of soil water-pore pressures and their effect on soil shear strength.

Mass movements of rock and soil in southeast Alaska are common on steep slopes resulting from glacial erosion and recent mountain building. These slopes are covered by thin, undifferentiated soils over bedrock or podzols developed on glacial tills of variable composition and thickness. Mass movements developed in these mantle materials are classified as debris avalanches or debris flows (Sharpe 1960; Highway Research Board 1958), ^{1/} depending on their overall water content and speed of movement. They result from loss of soil shear strength caused by both external and internal changes of stability. External changes include seismic movements, slope undercutting,

^{1/} Names and dates in parentheses refer to Literature Cited, p. 17.

or deposition on upper slopes. Internal conditions include piezometric head increase causing increased pore-water pressures and corresponding reductions in soil cohesion (Terzaghi 1950, pp. 83-123).

Bishop and Stevens (1964) indicated that clearcutting old-growth forests apparently accelerated debris avalanche and flow occurrence in the Maybeso Creek valley, Prince of Wales Island, Alaska (fig. 1). These mass movements developed on steep slopes in a glacial till soil, apparently triggered by high rainfall.

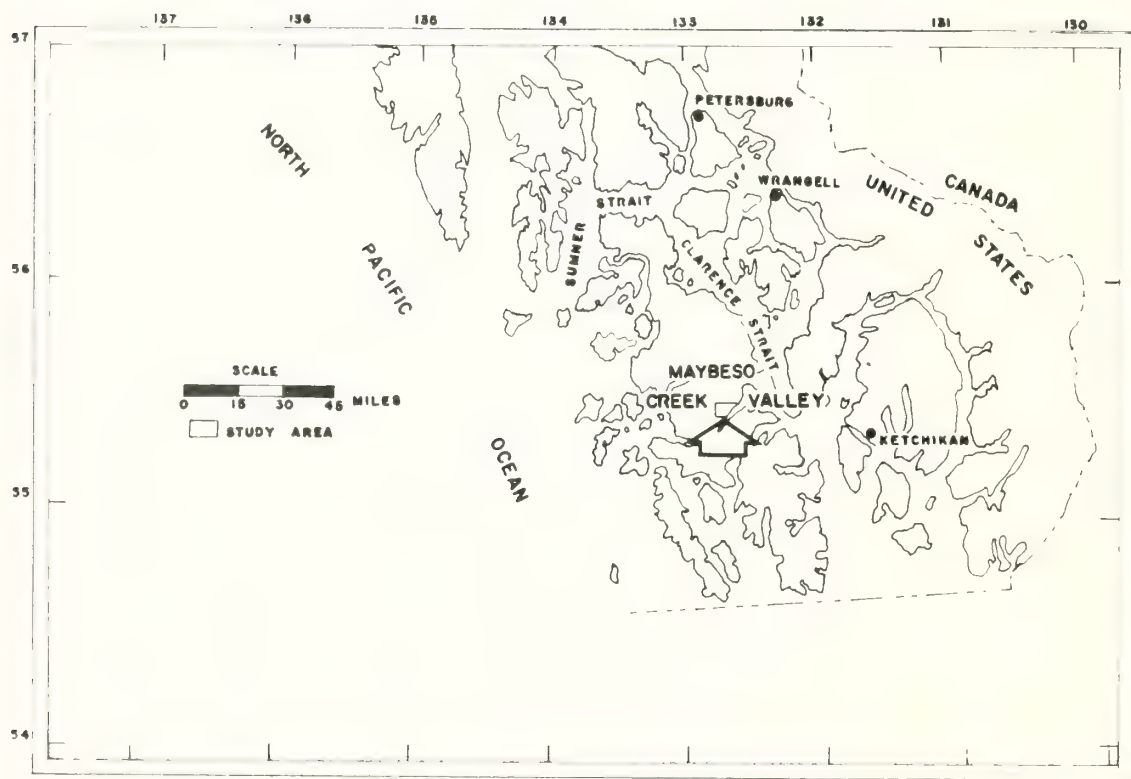


Figure 1.—Map of southeast Alaska showing location of Maybeso Creek valley.

STUDY AREA

Climate in the Maybeso Creek valley is cool, wet, and temperate. The mean annual temperature is 44° F. The mean annual precipitation is about 108 inches; rainfall is highest during the months of March, April, October, and November. Snow usually appears on upper slopes about mid-October. Recent debris avalanches and flows are associated with high rainfall in October (Bishop and Stevens 1964).

The drainage is a U-shaped glacial valley, floored by a variable thickness of glacial till extending to about 1,200-foot elevation. The valley is oriented in a west-northwest direction along the strike of the underlying bedrock. Bedrock is interbedded graywacke, shale, and black graphitic slate, dipping southwest into the valley at a variable angle. The southwest-facing slope is smooth and uniformly till covered, cut by several deep, narrow, V-shaped ravines. On the northeast-facing slope, indipping bedrock layers create a slope surface broken by benches and ridges with very few crosscutting ravines. The majority of debris avalanches and flows apparently affected by logging occur on the southwest-facing slope, either along the sides of the ravines or in incipient drainage depressions on the open slope.

The glacial till soils are in the Karta series.^{2/} They are well-drained, permeable soils with textures ranging from gravelly to silty loam. A representative Karta soil profile from the study area is described in table 1. A thick organic A horizon is underlain by a yellow-brown iron-stained horizon. Compact, unweathered till lies below the iron-stained horizon. Maximum thickness of the soil on these slopes is 3 feet. Mass movements begin in the iron-stained horizon and slide along the unweathered till surface.

Principal drainage is through deep, V-shaped ravines into Maybeso Creek. Little additional surface runoff occurs. Rain falling on the slope infiltrates the soil and moves along the upper surface of impermeable, unweathered till, concentrating in subsurface drainage-ways developed on the unweathered till surface. The shallow depressions on open till slopes are surface manifestations of these drainage-ways. Only during periods of very heavy rainfall has surface flow in

^{2/} Gass, C. R., Billings, R. S., Stevens, M. E. and Stephens, F. R. Hollis area soil management report. (In preparation for publication, U.S. Forest Service, Region 10.)

these depressions been observed. It is probable that these drainage depressions were formed initially by surface runoff following deglaciation and the beginning of Karta soil formation. These depressions have been subsequently enlarged by more rapid leaching and oxidation in the subsurface zones of maximum water concentration and by incipient slumping and minor erosion during infrequent periods of surface flow.

Table 1.--A typical Karta soil profile in the Maybeso Creek valley^{1/}

Horizon	Depth (inches)	Representative profile in study area
O1	5- 4	Living mosses and undecomposed leaves and twigs.
O2	4- 0	Reddish-black (10 R 2/1) peat; wet, nonsticky, nonplastic; many fine, medium, and few coarse roots; pH 3.5; abrupt wavy boundary.
A2	0- 1	Pale-brown (10 YR 6/3) gravelly silt loam; weak, fine, subangular blocky structure; wet, slightly sticky, slightly plastic, coarse fragments 40 percent by volume; many fine, medium, and few coarse roots, common fine and medium pores; pH 4.0; abrupt wavy boundary.
B2hir	1-14	Yellowish-red (5 YR 5/6) gravelly silt loam with dark-brown (7.5 YR 3/2) variegations; gravelly silt loam; weak, fine, and medium subangular blocky structure; wet, slightly sticky, slightly plastic; coarse fragments 40 percent by volume; common fine, few medium, and coarse roots, common fine and medium pores; pH 4.5; clear wavy boundary.
C1	14-17	Olive (5 Y 5/3) gravelly silt loam; massive; weakly cemented; 75 percent coarse fragments, few fine roots, pH 5.0; clear wavy boundary.
C2	17-21+	Olive (5 Y 5/3) gravelly silt loam; massive; strongly cemented by CaCO ₃ , with pockets of non-cemented, very porous glacial till; pH 5.5, 75 percent coarse fragments by volume. In transition zone to underlying unweathered till.

^{1/} From Charles Gass, soil scientist, Tongass National Forest, Alaska.

METHODS

Ten piezometers were installed during the 1964 and 1965 field seasons. The piezometer is a 1-1/2-inch, outside diameter, porous cylinder 6 or 12 inches long and connected to 1/2-inch, outside diameter, polyethylene tubing (fig. 2).

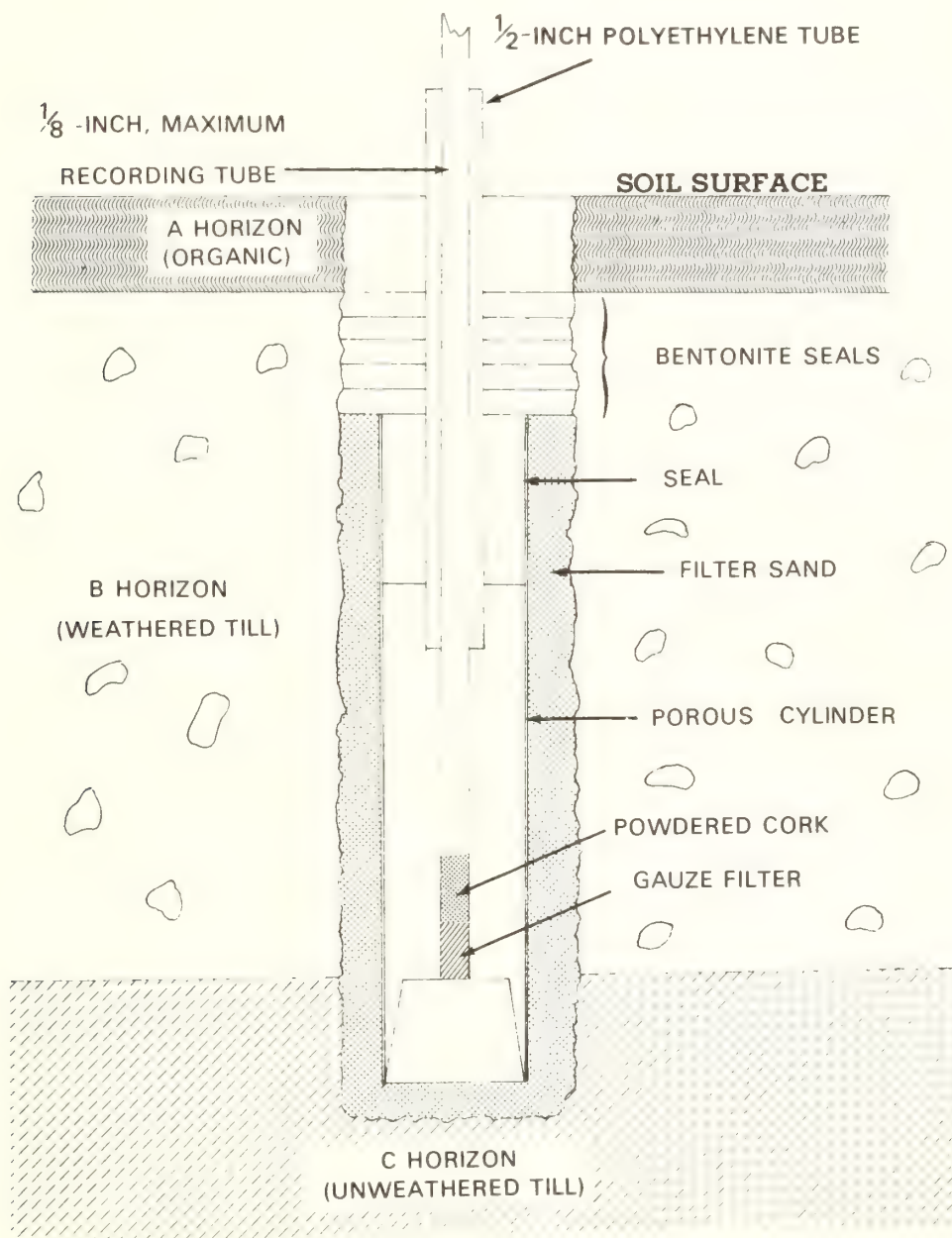


Figure 2.—Diagram of standard piezometer installation showing positioning of maximum recording tube.

The sites were on open slopes above or within the linear depressions. Slopes ranged between 35 and 40 degrees (about 70- to 85-percent grade). Piezometer locations are shown in figure 3. Several auger holes were drilled at each site to determine thickness of the weathered till. If water flowed into the hole freely and rose above the seepage zone, the site was judged satisfactory for piezometer installation. The hole was washed and filled with clean water, and 1 foot of clean, saturated sand was poured in. The porous cylinder was then inserted to the bottom of the hole with an excess head of water maintained in the cylinder at all times. After the height from the porous cylinder top to the ground surface was measured, saturated sand was poured in to fill the open space around the cylinder. A 6-inch layer of sand was poured in above the porous cylinder top, and the hole was then sealed with five layers of bentonite, each 1 inch thick. Piezometric head was measured by inserting a two-conductor wire into the polyethylene tube. When the wires touched the water surface, a circuit was completed and an ohmmeter needle deflected. Piezometric head was the difference between the length of wire inserted and the length from the open end of the polyethylene tube to the bottom of the porous cylinder.

The piezometers were read at time intervals determined by access difficulty and weather conditions. In the fall of 1964, readings were made in areas 1, 2, and 3 (fig. 3) every 3 days. More frequent readings of a modified network of piezometers was begun in 1965. Readings were limited to area 1 and vicinity, where the largest number of wells were located, and area 4 on the north-facing slope of Maybeso Creek valley.

In 1965, a reliable method was devised for recording absolute maximum piezometric rise. A polyethylene tube, about 1/8 inch inside diameter, with powdered cork in the bottom, was inserted into each operating piezometer (fig. 2). As the piezometric surface rose, powdered cork was carried upward on the water surface. When the water level fell, cork adhered to the tube walls at the point of maximum rise.

In 1964, rainfall was measured at a sea-level weather station near the mouth of Maybeso Creek. In 1965, rain was also measured with a recording gage placed in area 1, at an elevation of about 1,000 feet.

RESULTS

Figures 4 and 5 show the relationship of piezometric head to rainfall during the 1964 and 1965 fall rainy seasons. The curves of

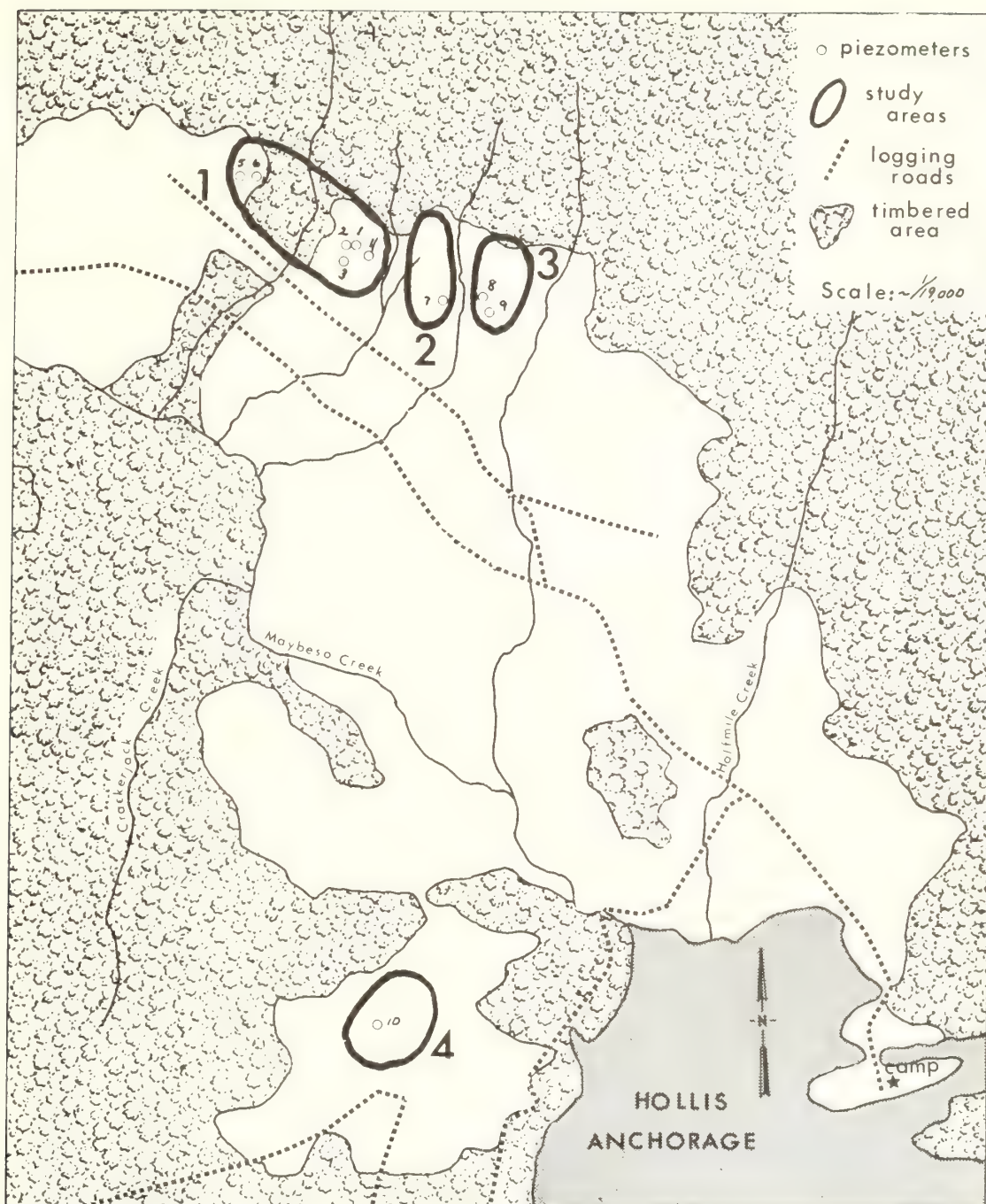


Figure 3.—Planimetric map of lower Maybeso Creek valley, Alaska, showing piezometer locations.

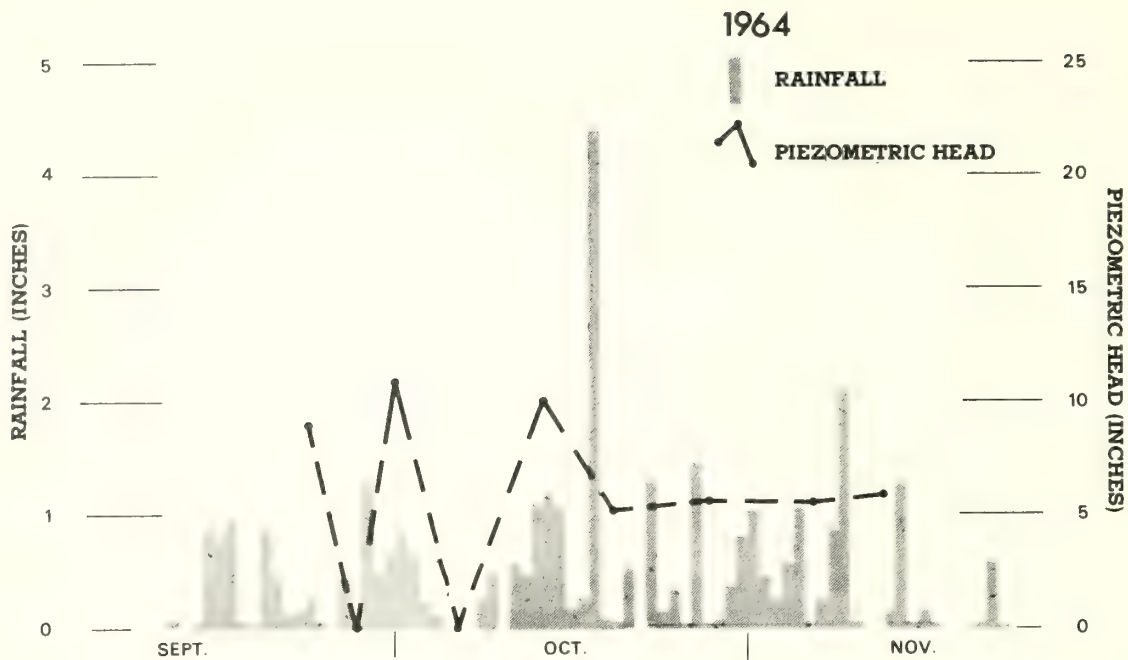


Figure 4.—Representative curve showing relationship between rainfall and piezometric head during the 1964 field season.

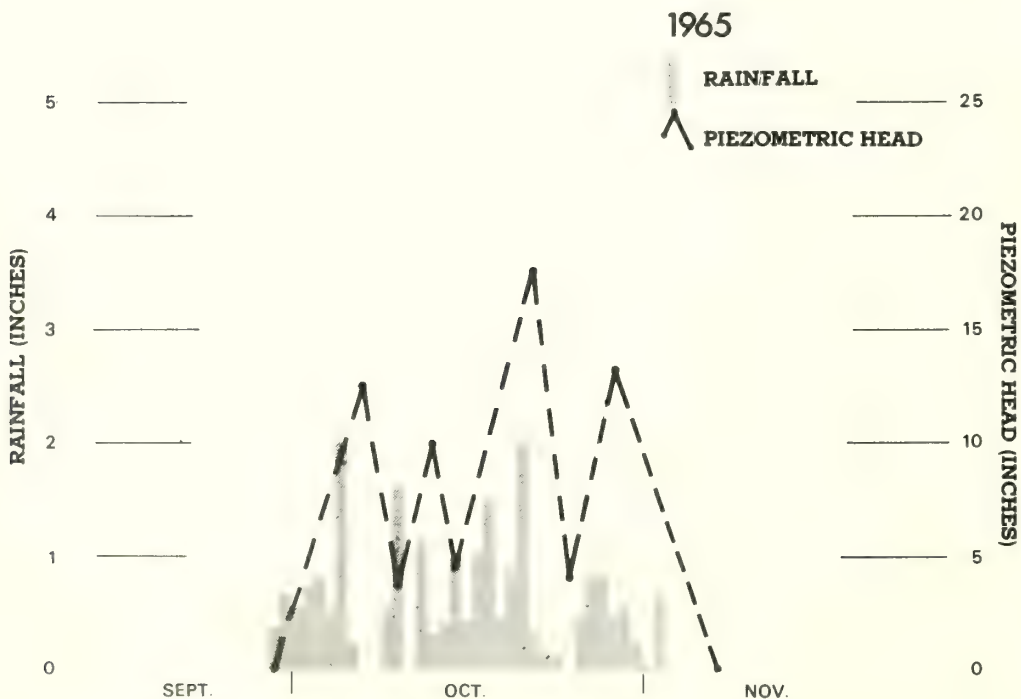


Figure 5.—Representative curve showing relationship between rainfall and piezometric head during the 1965 field season.

individual wells, although varying in magnitude of piezometric head, are markedly similar in relation to rainfall variations. All wells showed rapid fluctuations with rainfall variations, indicating relatively high permeability coefficients for the soil at the well sites. A short lag in piezometric rise occurred at the beginning of the rainy season for most wells, reflecting the time necessary for the soils to reach saturation at the interface between the B horizon and the compact till.

The 1964 piezometric head gradually leveled off late in the season despite undiminished rainfall. This coincides with the appearance of a permanent snow cover on the ridge above the well sites late in October. The 1965 season was short, and a permanent snow cover was absent during the recording period. During this time, no leveling off of the piezometric head curves occurred.

The more frequent reading of the 1965 piezometer network provided enough data for a regression analysis to be made (fig. 6). The resulting relationship is curvilinear, the basic units being average piezometric head and accumulated rainfall per day. The mathematical relationship is the polynomial:

$$Y = a + \frac{b}{X} + cX \quad (1)$$

where

Y = piezometric head in inches,

and

X = rainfall in inches per day.

Curve A is from the group of piezometers on the upper slope, at the top or just outside of the drainage depressions. Curve B is from piezometers lower on the slope and within drainage depressions. The correlation coefficients (r) for the points surrounding each curve are high. The following tabulation shows the regression equation and corresponding correlation coefficient for each curve:

	<u>Equation</u>	<u>r</u>
Curve A	$Y = 5.17 - \frac{0.232}{X} + 1.85X$	0.81
Curve B	$Y = 7.66 - \frac{0.331}{X} + 6.51X$	0.86

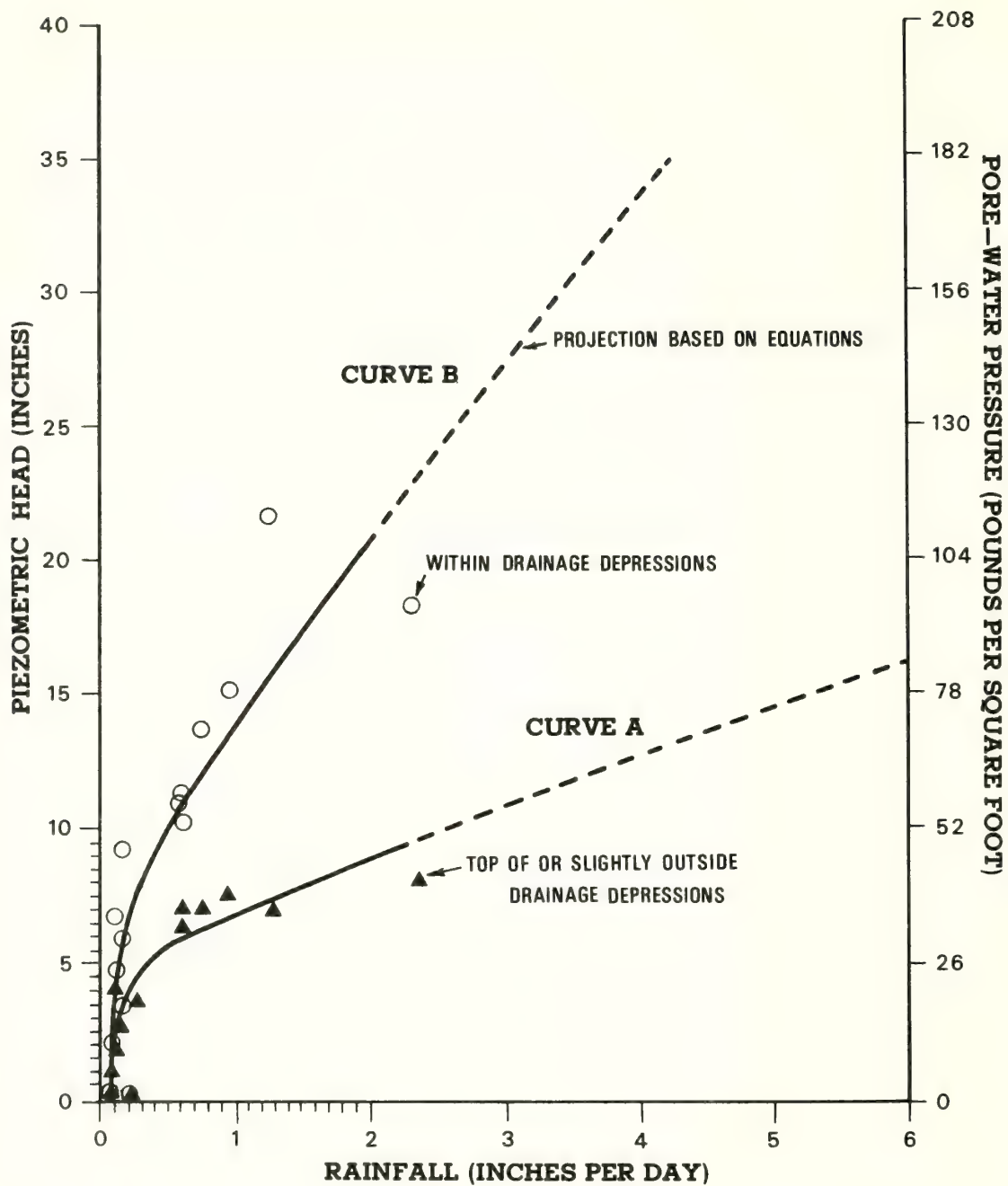


Figure 6.—Graph of average piezometric head vs. accumulated rainfall per day for two locations within preexisting drainage depressions.

Maximum piezometric heads for 1965 and the resultant pore-water pressures are shown in table 2.

Table 2.--Maximum piezometric head and pore-water pressure recorded for each well in the Maybeso Creek study sites during the 1965 field season

Well number	Maximum piezometric head during 1965 field season	Maximum pore-water pressure
	<u>Inches</u>	<u>Pounds per square foot</u>
1	32.0	166.4
2	10.5	54.6
3	18.5	96.2
4	7.0	43.4
5	20.0	104.0
6	10.6	55.12
7	11.0	57.2
8	6.0	31.2
9	6.0	31.2
10	27.5	143.0

The relationship between piezometric head and pore-water pressure is:

$$\mu = h_p \gamma_w \quad (2)$$

in which μ = pore-water pressure (pounds per square foot)

h_p = piezometric head (feet)

γ_w = unit weight of water (62.4 pounds per cubic foot)

Maximum values for piezometers 1, 3, 5, and 10, all located well within drainage depressions, are conspicuously high. The remaining piezometers occur above the depressions on the open slope.

DISCUSSION

Figure 6 demonstrates the effect of rainfall and slope position on piezometric head and the increase in piezometric head within drainage depressions. Since pore-water pressure is directly related to piezometric rise (equation 2) the correlations hold true also for pore-water pressure. Both curves begin at the same x -axis point, approximately 0.05 inches of rain. Beyond this point, piezometric head increases rapidly with increasing rainfall. After approximately 0.05 to 0.10 additional inch of rain, piezometric head increases more slowly. The curves are reliable for rainfall rates of 2.5 inches per day or less. Beyond this point, the curves are approximate, based on the curve equations. In actual practice, the upper limit of both curves is determined by complete saturation or thickness of the soil profile. In the case of curve A, this upper limit is not reached for the range of rainfall intensities considered in figure 6. For curve B, the limit is about 36 inches, or the average thickness of the soil in the slope area considered. Curve B shows greater piezometric head increase than curve A, indicating higher piezometric head due to increased hydrostatic pressure and flow volume downslope and within the depressions.

The magnitude of recorded and predicted pore-water pressures is great enough to strongly affect shearing strength of slide-prone soils in the Maybeso Creek valley. As an example, assume a soil 3 feet thick, completely saturated. At saturation, the piezometric head in the zone of failure is about 36 inches. From equation 2, we find the resultant pore-water pressure at the base of a column of this soil is 187 pounds per square foot. The effect of this pressure on soil shear strength can be determined by the Mohr-Coloumb theory of soil failure (Wu 1962).

The Mohr theory of rupture (Wu 1962, p. 71; Terzaghi 1963, p. 23, states essentially that failure in a plastic soil material occurs if the shear stress on any plane equals the shear strength of the material, and that the shear strength, S , is a function of the normal stress, σ , on that plane. Thus,

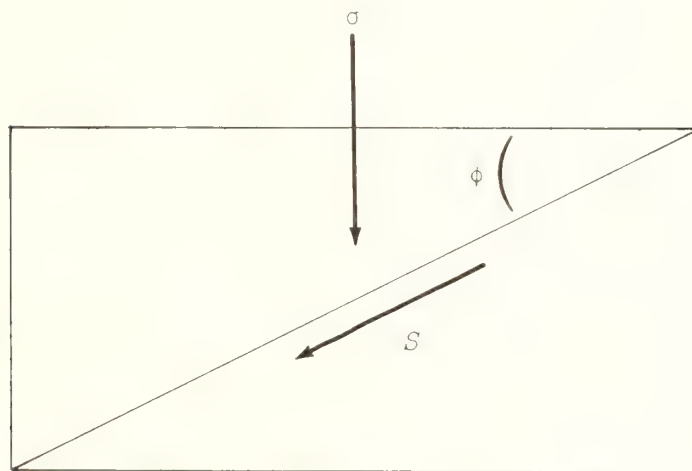
$$S = f(\sigma) \quad (3)$$

With Coloumb's definition of the function, f , as a linear function of the normal stress or the stress acting at an angle, ϕ , to the shear stress, the equation $S = f(\sigma)$ can be written as

$$S = c + \sigma \tan \phi$$

In this equation, known as Coloumb's equation, S is shear strength, c is a constant called cohesion reflecting the resistance of the soil to

shear along a surface, σ is total normal stress, and ϕ is the angle of internal friction (Wu 1962, p. 71; Terzaghi 1963, p. 19) (fig. 7).



ϕ = angle of internal friction
 σ = saturated unit weight of soil
 S = shear stress on block

Figure 7.—Diagram of stress relationships on a unit block of soil.

This equation represents the strength as a factor of total normal stress applied to the soil mass at failure, which includes both an effective stress transmitted through points of contact between individual soil grains and a neutral stress produced by the weight of the water, often called pore-water pressure. Since we are primarily interested here in the effect of pore-water pressure variations, Coloumb's equation can be expressed under conditions of effective stress where effective stress, $\bar{\sigma}$, equals total normal stress, σ , minus pore-water pressure, μ . Coloumb's initial equation becomes

$$S = \bar{c} + (\bar{\sigma}) \tan \bar{\phi} \quad (4)$$

where S = soil shear strength (pounds per square foot)

$\bar{c}$ = effective cohesion of soil (pounds per square foot)

$\bar{\sigma}$ = effective stress

$\bar{\phi}$ = effective angle of internal friction of soil degrees

The above equation shows how variations in pore-pressure affect the strength of the soils. An increase in pore-water pressure decreases the total normal stress and thus decreases the shear stress of the soil. The reverse is true for a decrease in pore-water pressure, assuming c and ϕ remain constant in both cases. Karta soil is cohesionless with a 37° angle of internal friction and a unit weight of 95 pounds per cubic foot. Weight of the 1- by 1- by 3-foot soil mass is 285 pounds (95 pounds per cubic foot $\times$ 3).

Applied to equation 4, these values at zero pore-water pressure equal 214 pounds per square foot soil shear strength.

$$S = 0 + 285 (0.75355) = 214$$

With the addition of pore-water pressure, soil shear strength is reduced to 74 pounds per square foot.

$$S = 0 + (285-187) 0.75355 = 74$$

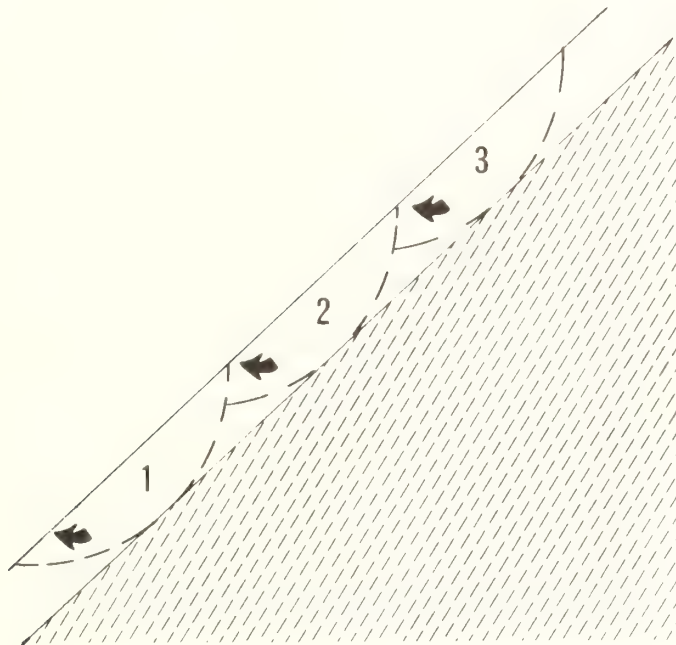
Shear strength of the soil mass affected by pore-water pressure is decreased by 65 percent.

Development of a fairly constant piezometric head late in 1964 and its rapid disappearance following the accumulation of a permanent snow cover above the well sites has implications. Permanent snow on the ridges may modify large piezometric fluctuations by maintaining a fairly constant supply of water to the slope soils. This means a fairly constant flow rate and piezometric head for the saturated zone of soil water. Flow rate in the zone of saturation is large enough to compensate for most additions of water to the soil by natural rainfall. The constant water supply compensates for most decreases resulting from decreasing rainfall. The fairly low pore-water pressures maintained following permanent snow accumulation may effectively terminate the fall period of most active sliding.

Within drainage depressions, piezometric heads are high and increase downslope. This is due to pore-water concentration and

resultant increases in volume. The increased pore-water pressures downslope probably are the cause of numerous small "slip-outs" and debris avalanches occurring in the lower parts of many drainage depressions. Thus, drainage depressions may develop and enlarge by small-scale slides occurring progressively upslope. A slip-out in a subsurface drainage channel probably first occurs low on the slope where pore-water pressures are greatest. Above this slip-out, later ones may occur due to high pore-water pressures and reduced shear-ing strength in the soil mass caused by undercutting (fig. 8).

Figure 8.—Diagram illustrating the possible development of progressive slope failure upslope within areas of concentrated subsurface water flow.



The regression equations for curves A and B (fig. 6) may be used to forecast piezometric head for rainfall amounts up to 2.5 inches at given slope locations. These equations also provide an approximation of piezometric levels at slope failure. Bishop and Stevens (1964) reported a 6.41-inch rain accumulation during October 14-15, 1961, a period of massive landslide occurrence. Five inches of rain fell in one day. Since the slides occurred within the drainage depressions, a calculation using curve B equation indicates a corresponding

piezometric head in excess of 45 inches. Since soils in the area of initial slope failure do not exceed 36 inches in thickness, it is probable that the soils were thoroughly saturated when sliding occurred. Rainfall frequency data for Alaska (Miller 1963) indicate a 2- to 5-year occurrence interval for rainfall of this magnitude. The frequency of occurrence agrees with the other extensive mass movements in 1959 (Bishop and Stevens 1964).

CONCLUSIONS

The present study indicates a close relationship between rainfall and pore-water pressure development. As rainfall increases, pore-water pressure increases, rapidly at first, but at a decreasing rate as rainfall continues, reaching an upper limit determined by thickness of the soil profile. Pore-water pressures also increase downslope and within drainage depressions.

A modifying effect on high pore-water pressures with the arrival of a semipermanent snow cover above the till slopes is also suggested. Thus, the arrival of the first fall snows may terminate the season of maximum slide activity.

The regression equations based on data relating piezometric head and pore-water pressure to rainfall provide a means for estimating head pressures for given rainfall amounts and slope locations. Calculation of piezometric head for the maximum recorded rainfall during past slide activity in the study area indicates that the sliding soils were probably completely saturated and therefore subjected to maximum pore-water pressures at time of failure.

Finally, the effect of pore-water pressure on slide susceptibility of the glacial till soils is indicated by a calculated decrease in shear strength of 65 percent at total saturation.

LITERATURE CITED

Bishop, D. M., and Stevens, M. E.

1964. Landslides on logged areas in southeast Alaska. U.S. Forest Serv. Res. Pap. NOR-1, 57 pp., illus.

Highway Research Board.

1958. Landslides and engineering practice. Highway Res. Board Spec. Rep. 29, Nat. Acad. Sci. Nat. Res. Counc. Pub. 544, 229 pp., illus.

Miller, John.

1963. Probable maximum precipitation and rainfall frequency data for Alaska. U.S. Weather Bur. Tech. Pap. 47, 20 pp., illus.

Sharpe, C. F. S.

1960. Landslides and related phenomena. 127 pp., illus. New Jersey: Pageant Books, Inc.

Terzaghi, Karl.

1950. Mechanism of landslides: in application of geology to engineering practice. Geol. Soc. Amer. Berkley Vol.

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1963. Theoretical soil mechanics. 510 pp., illus. New York: John Wiley and Sons.

Wu, T. H.

1962. Soil mechanics. 242 pp. East Lansing: Michigan State Univ.

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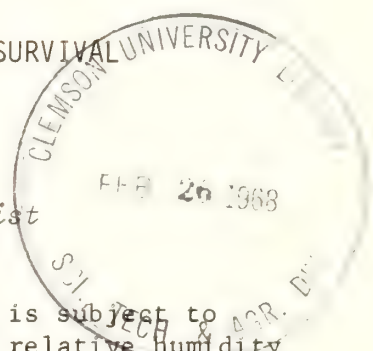
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PNW-69

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INFLUENCE OF CAMBIAL CONTACT LENGTH ON GRAFT SURVIVAL AND LEADER ELONGATION IN DOUGLAS-FIR

by Donald Copes, Associate Plant Geneticist



First-year graft survival under field conditions is subject to many variables. Influence on grafting success of low relative humidity and temperature (Holst 1956, Nienstaedt et al. 1958, Shippy 1930, Sirton 1931, Webb 1961), climatic conditions and graft type (Orr-Ewing and Prideaux 1959, Mowat and Silen 1957), poor cambial matching (Hartmann and Kester 1959), and scion pretreatment (Zak 1955) has been reported. One factor influencing early survival, largely overlooked by past investigators, is the length of matched cambial edges between the scion and stock. This study, although originally aimed at investigating the long-term influence of graft types on the appearance of incompatibility symptoms between scion and stock, was found to yield fairly conclusive evidence that length of cambial contact was an important factor in 1st-year survival.

METHODS

A complete description of study methods that would emphasize graft types would serve little purpose to the reader. In this publication, methods pertaining to length of cambial contact are highlighted. Great variation in lengths of cambial contact was automatically obtained by making graft types differing in number of sides on which potential union areas could develop. Length of vertical cuts also varied considerably between graft types.

Graft types studied were splice, long cleft, short cleft, stub cleft, side, saddle, and top notch. Five of the seven graft types had 12 grafts of each in which the cambial edges of the stock and scion fitted together on both sides of the graft. Twelve grafts of each

type were also made where the cambial edges of the scion and stock were fitted together on only one side of the stem. This latter condition resulted from grafting small-diameter scions on large-diameter stocks. Well-matched scion and stock grafts were made by grafting scions and stock of exactly the same stem diameter (fig. 1). Two graft types, which are exceptions in study design just stated, were the side graft and the stub-cleft graft. In the side grafts, only the condition where both sides of the graft matched exactly was used. In the stub-cleft group, only one side of the graft could be made with matched cambiums because of the extreme difference in scion and stock diameters. All grafts used were standard types and are illustrated in most plant propagation books such as Kains and McQuesten (1942). No detailed descriptions of graft types will be presented because comparisons between types were not possible. The major factor found to influence graft behavior was length of cambial contact between stock and scion.

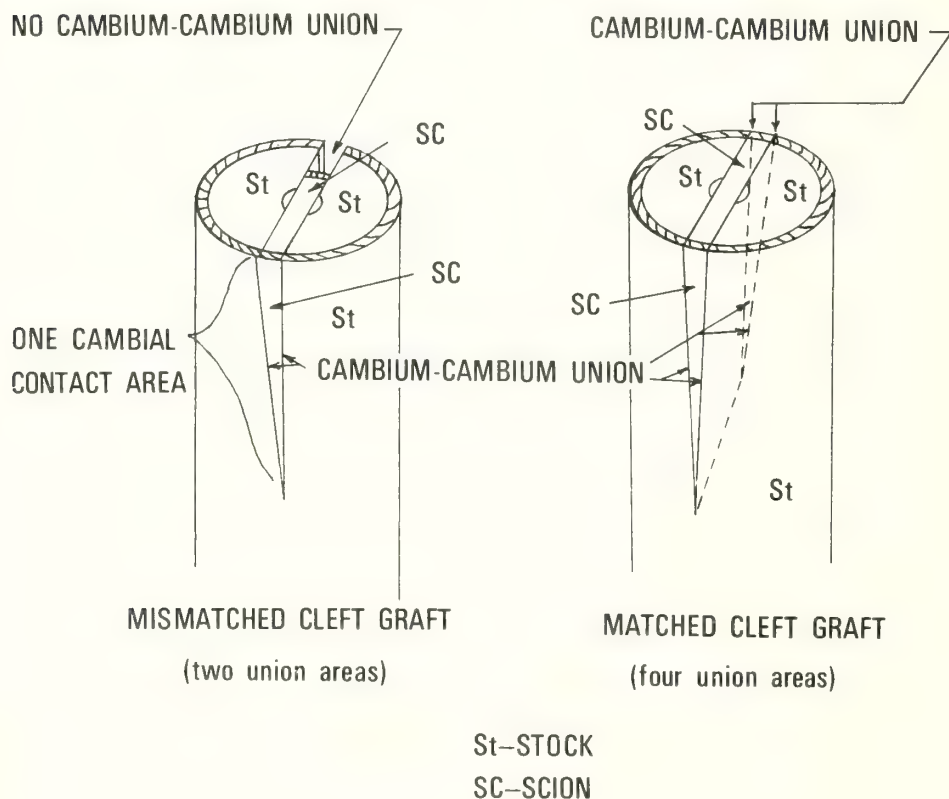


Figure 1.--Cleft graft unions, as seen in the matched and mismatched stock-scion cambium positions.

Douglas-fir grafts were made by cutting off branch tips and grafting them upon the same branch from which they were cut. With this technique, no stock-scion interaction effects produced by unlike genotypes could occur. No scion storage problem was involved with immediate regrafting. All stock trees were decapitated about 15 cm. above the 1964 whorl, and two stub-cleft grafts were placed upon each stub. All other graft types were made on the tips of the 1964 branches. Twelve branches of each stock tree were grafted. Only 1-year-old scion wood of each tree was grafted. Scions were grafted upon 1-year-old stock wood, except for the stub-cleft grafts which were placed on wood of older origin. Stub-cleft and side grafts were the only types made with scions collected from stock branches other than those to which they were originally attached. This resulted because of the nature of the graft types.

The length of the cut surface within each graft type was made as uniform as possible, but between graft types the length of cut surface varied greatly (table 1). This latter fact ruled out a valid comparison between graft types. Measurement of the actual cambial contact length in each graft was taken 4 months after grafting. A ruler was placed along the union zone and the distance along which cambial contact existed between the stock and scion was measured to the closest millimeter.

Actual vertical cuts made on the stocks averaged 12.5 mm. for the short-cleft grafts and 63.5 mm. for the long-cleft grafts; a range of 51 mm. The amount of connecting cambial tissue between the graft types was further influenced by the number of union areas in which cambial contact between the stock and scion could occur. For example, a matched long-cleft graft could be considered to have four cut cambial edges each about 64 mm. long, whereas a mismatched long-cleft graft could have only two cut edges each about 63 mm. long (fig. 1). These two graft types differed by 130 mm. (64×4 minus 63×2) of cambial contact (table 1). The number of cut edges of contact varied from one to four, depending upon the graft type. Mismatched top-notch grafts and splice grafts had only one edge of cambial contact. Two edges were found on mismatched stub-cleft, saddle, short-cleft, and long-cleft grafts and on matched grafts of side, top-notch, and splice graft types. Four contact edges were present in matched saddle, short-cleft, and long-cleft grafts. Both splice graft treatments contain a component for horizontal matched cambium as well as for vertical cuts. Matched splice grafts had 10 mm. added and mismatched splice grafts had 5 mm. added to the vertical edge totals.

Length of scion tissue above the graft union was uniformly near 5 cm. Tissues on the scion through which water loss could occur should have been about equal between and within graft types. All needles and buds were left undisturbed on the upper scion areas.

Observations on scion elongation were made on August 11, 1966, when all 1966 elongation was completed. Survival was recorded on March 27, 1967.

Table 1.--First-year graft survival and scion elongation, by graft types and length of matched cambial edges

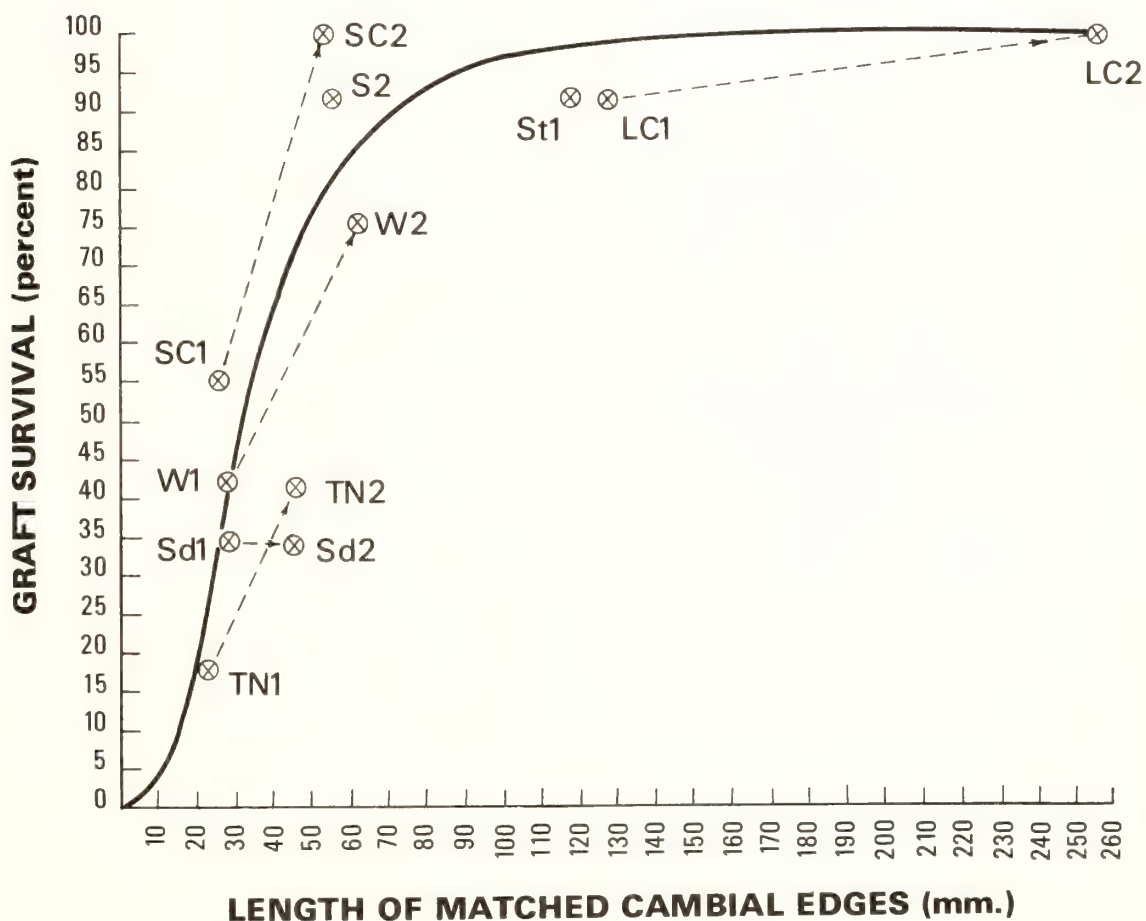
Graft type	Scion and ¹ / _{stock match}	Average length of vertical cut on stock	Average length of cambial contact between stock and scion	Average length of scion elongation (on August 11, 1966)	Survival on March 27, 1967
			----- Millimeters -----		Percent
Splice	Match	25	60	176	75
Splice	Mismatch	24	29	50	42
Long cleft	Match	64	256	257	100
Long cleft	Mismatch	63	126	189	92
Short cleft	Match	13	52	135	100
Short cleft	Mismatch	12	24	167	54
Saddle	Match	11	44	135	33
Saddle	Mismatch	14	28	66	33
Top notch	Match	22	44	51	42
Top notch	Mismatch	23	23	150	17
Side	Match	27	54	150	92
Stub cleft	Mismatch	58	116	274	92

¹/ Number of grafts is 12 except for stub cleft with 22.

RESULTS AND DISCUSSION

No assessment will be attempted concerning the type of graft that will result in highest survival the 1st year, as might be done if the original intent of the study were followed. When it was seen that within each graft type the matched grafts survived better than the mismatched grafts, the possibility of a relationship between survival and length of cambial contact was analyzed. Table 1, for example, shows that 1st-year graft survival between types ranged from 17 to 100 percent. However, most of this variation, as shown in table 1, proved to be related to length of matched cambium. Statistically, the relationship between survival and cambial contact was curvilinear and highly significant ($r = 0.74^{**}$, 10 d.f.). Fifty-five percent of the variation was attributed to length of cambial contact (fig. 2).

Figure 2.--Field graft survival as related to length of matched cambial edges and graft types after 1 year.



The data indicate that field graft survival is very dependent upon water movement between the stock and scion. Grafts with long cambial contact areas have a greater surface through which water can pass. In the first 2 weeks following grafting, water must move from the stock to the scion through parenchyma cells rather than through mature tracheids (Braun 1962). During periods of high temperature and low relative humidity, grafts with little connecting tissue could become desiccated, and the grafts might die. If, as suspected, early graft failure is often due to scion desiccation, length of cambial contact would be of greatest importance when grafting is followed by warm, dry weather. Under this assumption, grafts made with long areas of cambial contact would survive better under those conditions than grafts made with extremely short unions.

As in the case of survival, grafts with more cambial contact generally had more 1st-year scion elongation than grafts with short unions (fig. 3). The relationship was linear and highly significant ($r = 0.71^{**}$). Fifty percent of the variation observed could be explained by cambial contact length.

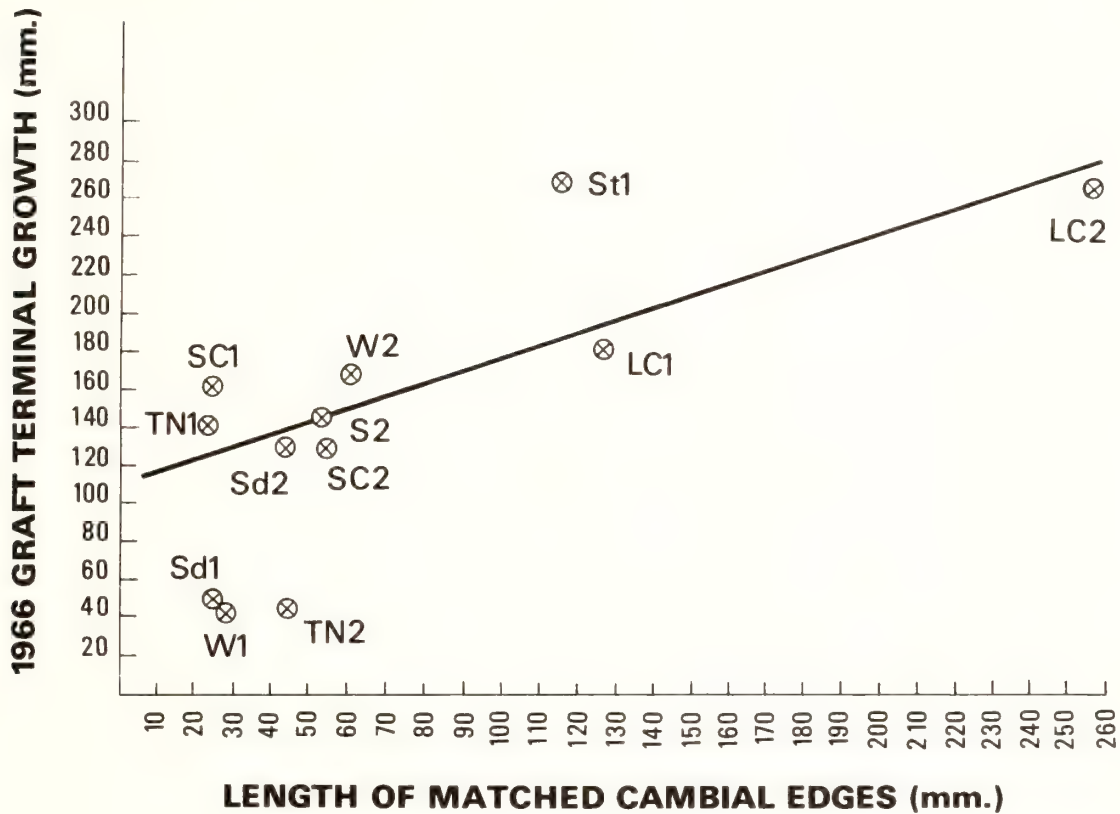
An interesting relationship between graft growth and graft position on the stock was indicated by the stub-cleft graft type. Its growth of an average of 274 mm. exceeded all other graft types. This was surprising when it is noted that the stub-cleft graft had an average of 116 mm. of cambial contact; however, the matched long-cleft had 256 mm. of cambial contact, yet its elongation averaged only 257 mm. This deviation from the expected is partially explained by the fact that stub-cleft grafts were made on the trees' main stems, whereas the other graft types were made on the tips of lateral branches.

This study presents rather persuasive evidence that cambial contact length is an important factor in early survival of Douglas-fir grafts. Because of study design, it is not possible to make valid comparisons between graft types due to the lack of similar lengths of cambial contact between graft types. There is some indication that survival of certain types is influenced by cambial contact length more than survival of other graft types (compare SC-1 and SC-2 and Sd-1 and Sd-2 in fig. 2). A study to test survival between graft types must hold constant the length of cambial contact. Such a test is underway.

SUMMARY

A study of seven types of Douglas-fir field grafts indicated that survival was dependent upon length of matched cambial union areas between stock and scion. For grafts with no more than 5 cm. of stem and foliage above the graft union at time of grafting, graft survival decreased almost linearly as the contact area became less than 75 mm. Little additional gain in survival was obtained by lengthening the matched cambial edges beyond 75 mm. First-year leader elongation was also influenced by cambial contact length, though not as strongly as survival.

Figure 3.--First-year scion elongation as influenced by length of matched cambial edges and graft types; August 11, 1966.



LITERATURE CITED

- Braun, H. J.
1962. Water economy and water supply in tree grafts.
Z. Bot. 50: 389-404.
- Hartmann, Hudson T., and Kester, Dale E.
1959. Plant propagation principles and practices. 559 pp.,
illus. Englewood Cliffs, N. J.: Prentice-Hall, Inc.
- Holst, M. J.
1956. Scion storage and graft protection in the spring grafting
of red pine. Can. Dep. North. Aff. Natur. Resources,
Forest Res. Div. Tech. Note 29, 11 pp., illus.

- Kains, M. G., and McQuesten, L. M.
1942. Propagation of plants. 639 pp., illus. New York: Orange Judd Publishing Co.
- Nienstaedt, Hans; Cech, Franklin C.; Mergen, Francois; and others.
1958. Vegetative propagation in forest genetics research and practice. J. Forest. 56: 826-839, illus.
- Orr-Ewing, A. L., and Prideaux, D. C.
1959. Grafting methods for the Douglas fir. Forest. Chron. 35: 192-202, illus.
- Mowat, Edwin L., and Silen, Roy R.
1957. A test of grafting ponderosa pine. U.S. Forest Serv. Pacific Northwest Forest & Range Exp. Sta. Res. Note 155, 5 pp., illus.
- Shippy, W. B.
1930. Influence of environment on the callousing of apple cuttings and grafts. Amer. J. Bot. 17: 290-327.
- Sitton, B. G.
1931. Vegetative propagation of black walnut. Mich. Agr. Exp. Sta. Bull. 119, 45 pp.
- Webb, C. D.
1961. Field grafting loblolly pine. N. C. State Coll. Agr. & Eng. Sch. Forest. Tech. Rep. 10, 33 pp.
- Zak, Bratislav.
1955. The grafting of shortleaf and other pine species. U.S. Forest Serv. Southeastern Forest Exp. Sta. Sta. Pap. 59, 13 pp., illus.

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PNW-70

November 1967

A SIMPLE METHOD FOR DETECTING INCOMPATIBILITY IN 2-YEAR-OLD GRAFTS OF DOUGLAS-FIR

by

D. L. Copes, *Associate Plant Geneticist*

Introduction

Graft incompatibility has become one of the more important problems facing Douglas-fir orchardists. It has been 10 years since large-scale grafting was started in Oregon and Washington Douglas-fir seed orchards. Some mortality from graft incompatibility began to appear as early as the fall of the year of grafting. Since that time, more losses have occurred each year in the early incompatible clones (E.I.). An even more disturbing loss has resulted from delayed incompatibility (D.I.). Clones with D.I. showed good early survival and no external symptoms of incompatibility but in later years developed a scion overgrowth symptom--such as first described by Duffield and Wheat.^{1/} Finally, many overgrown grafts died, and many more are still dying. The seriousness of the problem is indicated by a recent inventory, now in our files, made by three seed orchard operators. The survey of 42 clones revealed that 46 percent of the 3,059 grafts, made 4 to 9 years previously, were dead due to incompatibility. The 46-percent loss is not the final incompatibility value, as many surviving grafts already show the scion overgrowth symptom and will probably die.

^{1/} Duffield, J. W., and Wheat, J. G. Graft failures in Douglas-fir. J. Forest. 62: 185-186. 1964.

Early detection of incompatibility in new clones would be of great value to Douglas-fir seed orchardists. Unfortunately, D.I. clones go undetected for a number of years. During that time, the rootstocks become too large for grafting with replacement clones. This necessitates costly roguing of large stocks. Also, the newly planted stocks and later grafted scions are generally in a subordinate stand position in the developing orchard.

Mosse^{2/} and Herrero,^{3/} with plum and pear grafts, and Lapins,^{4/} with apricot grafts, demonstrated that early tests for incompatibility are possible for some fruit trees. They detected anatomical symptoms in 2d-year grafts which could be used to make accurate estimates of incompatibility. Furthermore, the field performance of older grafts from the same clones was closely correlated with predictions based on 2d-year graft anatomy. Copes^{5/} later discovered 2d-year symptoms in Douglas-fir grafts which could be used to accurately detect delayed incompatibility. This paper describes how orchardists can make use of this technique.

Basis of Testing

To accurately estimate graft incompatibility, two factors must be considered: amount of E.I. mortality and amount of wound xylem caused by D.I. It is necessary, however, to separate E.I. losses from those caused by grafting technique. Any failure before a graft is 4 months old is considered a loss from faulty grafting. Graft failures between the 4th and 24th months are considered losses caused by E.I.

^{2/} Mosse, B. Further observations on growth and union structure of double-grafted pear on quince. J. Hort. Sci. 33: 186-193. 1958.

Mosse, B. Graft incompatibility in plums: Observations on a ten-year-old field trial. J. Hort. Sci. 35: 260-265. 1960.

^{3/} Herrero, J. Studies of compatible and incompatible graft combinations with special reference to hardy fruit trees. J. Hort. Sci. 26: 186-237, illus. 1951.

^{4/} Lapins, K. Some symptoms of stock-scion incompatibility of apricot varieties on peach seedling rootstocks. Can. J. Plant Sci. 39: 194-230.

^{5/} Copes, Donald L. Graft incompatibility and union formation in Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco. 187 pp. 1967. (Unpublished Ph.D. thesis on file at Univ. Idaho, Moscow.)

The second factor, the amount of D.I., is less easy to describe since it is concerned with the development of abnormal woody tissues which appear in the xylem union at the start of the second growing season. It will be best, therefore, to consider (1) what the D.I. symptom is, (2) how the symptom develops, and (3) how this symptom can be used in a test for incompatibility. Delayed incompatibility in Douglas-fir is always associated with the formation of wound-xylem areas. The presence of wound xylem is a positive symptom of D.I.^{6/} Wound-xylem areas are composed of living callus cells, disorganized tracheids, and, sometimes, engulfed areas of dead bark cells. When examined late in the second growing season, each wound area appears as a small island of abnormal tissue (fig. 1). Wound xylem caused by incompatibility is found in all union zones where stock and scion cambial tissues merge (fig. 2).

Second, at the start of the second growing season, delayed incompatible grafts have dead cambial tissues in each union area where the stock and scion cambiums join. Grafts which do not die of E.I. undergo at this time a natural regrafting of stock and scion tissues. Living cells of the bark form new callus tissue on both the scion and stock sides of the dead cambium and, after much cell division, form a bridge of living tissue between the stock and scion. A cambium later differentiates in each bridge area, and for the remainder of that growing season, relatively normal tracheids are formed. This regrafting process results in cell types and tissue structures that are similar to those occurring after man-made grafting (fig. 2). The formation of callus and the resulting bridge are part of the characteristic tissue which I have termed "wound-xylem areas."^{7/}

The same pattern of cambial necrosis and natural regrafting occurs at the start of the third, fourth, and every following year until scion death (fig. 2). Death of D.I. grafts occurs after they fail to regraft. Regraft failure causes a girdling effect, and the scion develops the characteristic overgrowth described by Duffield and Wheat.^{8/} When the roots starve from lack of photosynthates, or when the scion dies of desiccation after the connecting xylem becomes nonfunctional, the graft can be said to have died of D.I. Death may occur in the same year of regraft failure, or the graft may live as long as another 4 years. All grafts that form this type of wound-xylem area must be classified as a potential source of loss.

^{6/} See footnote 5.

^{7/} See footnote 5.

^{8/} See footnote 1.

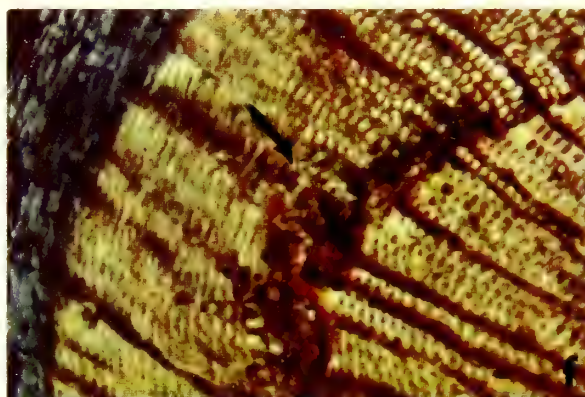
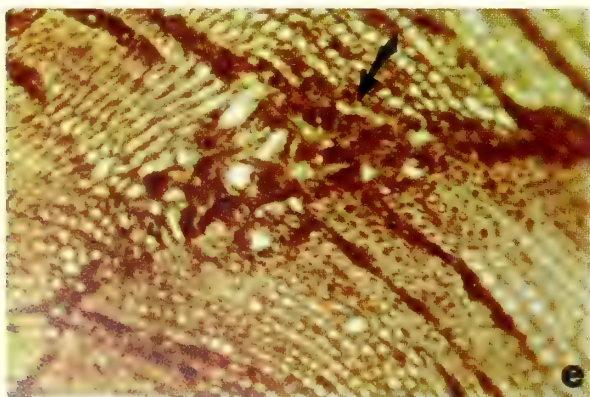
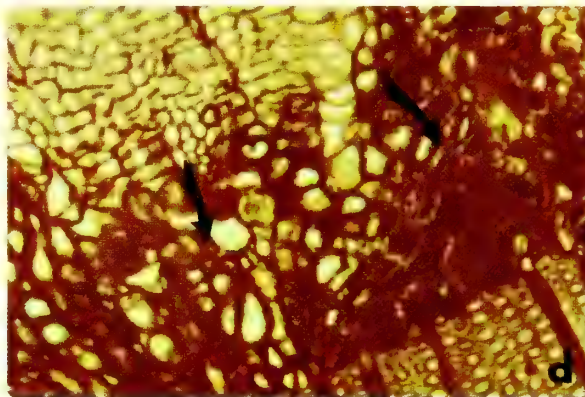
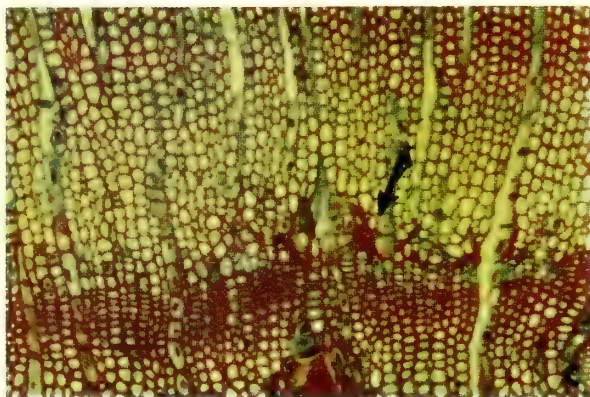
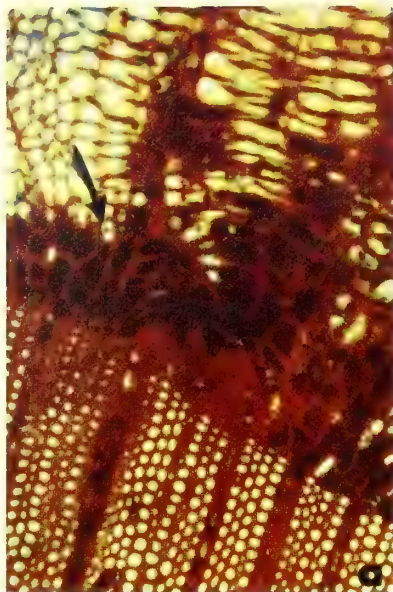
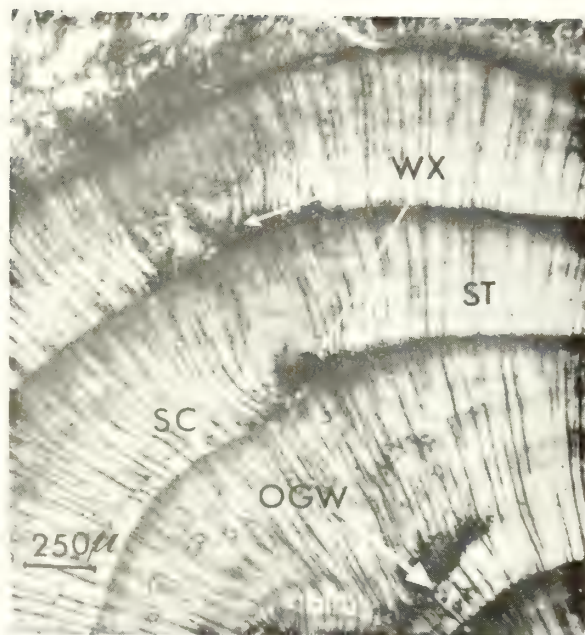


Figure 1.--Typical wound-xylem areas are shown in union zones of incompatible grafts at the start of the second season following grafting. The 1966 xylem is toward the bottom of each photograph, and 1967 xylem is toward the top. Sections shown in photos a, b, c, and f were stained with both safranin and fast green, whereas those in photos d and e were stained with safranin only. The arrows point to the wound areas.

Figure 2.--Wound-xylem areas formed in one union zone of an incompatible graft after natural regrafting in the second and third growing seasons. Note the similarity between those areas and the original graft tissues formed as a result of man-caused grafting. (Wound xylem, WX; original graft wound, OGW; scion, SC; stock, ST.)



Not all wound areas are necessarily symptoms of incompatibility. Frost damage and poor grafting technique can cause the formation of wound areas resembling those due to incompatibility, but they can be differentiated. First, frost damaged tissue is not found solely in the union zones, as are wound-xylem areas. Second, poor grafting technique can occasionally cause the formation of wound-xylem areas closely resembling those found in incompatible grafts, but such areas occur only where a physical disruption of the union exists. Also, other union zones within the same graft show no evidence of wound xylem, whereas a truly incompatible graft would show wound xylem in all areas where stock and scion cambiums were in contact.

Requirements for an Early Test for Incompatibility

An early test for incompatibility will require the following steps:

1. Establishment of at least 10 grafts of each clone for testing; allow a few extras for technique failures.
2. Separation of grafting technique losses from E.I. losses.
3. Sectioning of graft unions into thin cross sections to determine the presence or absence of wound-xylem areas (D.I.).

Early testing of new clonal selections before they are grafted into the orchard will be of great value to orchardists.

Grafts for the incompatibility test can be made on either potted, nursery, or wildling stocks. It is possible that the most accurate screening for incompatibility will be obtained when graft techniques, time of grafting, stocks, and environmental conditions closely match those which are found in actual orchards. Since orchard grafting is done on many different stocks, it is desirable to test-graft new clones on as many stock genotypes as possible. No more than one graft of each clone should be made on a single stock, but it is possible to make efficient use of available stocks by grafting more than one clone on each stock. Two, three, or four grafts of a clone on the same stock will not tell the orchardist any more about the compatibility of that scion and stock combination than will a single graft. Grafts placed on branches are as accurate for test purposes as grafts placed on main leaders.

Collections made before growth starts in the 2d year will not show wound-xylem areas or tell the orchardist much concerning the D.I. of the clones being tested. The preferred collection time is either in late summer or fall after most diameter growth has ceased. Wound-xylem areas are checked more easily if they are surrounded by normal tissue.

Screening can also be done on grafts older than 2 years, but sectioning is difficult with the large unions of older grafts. Therefore, 2-year-old unions are preferred for screening.

Screening Procedure for Individual Clones

The technical procedure for testing clones for incompatibility is as follows:

A. Estimating Early Incompatibility

1. For each clone, subtract the mortality losses through the first 4 months from the total number of grafts. The difference is the test base for estimates of incompatibility.
2. For each clone, record the number of grafts which died between 4th month and time of graft union collection. This value represents losses from early incompatibility.
3. To determine the percentage of early incompatibility for each clone, divide the value from step 2 by the test base obtained in step 1 and multiply the results by 100. The orchardist will have to decide which clones should be eliminated from testing owing to severe losses from E.I.

B. Estimating Delayed Incompatibility

1. Collect unions of surviving grafts of each clone during the summer or fall of the 2d year. Sever the stem immediately above and below the union. Place the unions in vials or jars containing a 30- to 50-percent solution of isopropyl or ethyl alcohol. The grafts can be stored in this solution indefinitely. Allow the grafts to remain in the solution for at least 1 day before proceeding with step 2.
2. Remove the grafts from the solution immediately before cutting cross sections from the middle of the union. A razor blade or an extremely sharp grafting knife can be used for cutting. Cut the sections as thin as possible. Only one good section is needed from each graft, but several should be cut in case the first ones are too thick, badly cut, or poorly stained.
3. Place the cut sections for at least 10 seconds in a small dish containing 50-percent solution of ethyl or isopropyl alcohol. This will prevent the sections from drying out and prepare them for step 4. A pair of tweezers is a useful tool for moving sections in steps 3 to 8.
4. Move the sections into a dish of safranin.^{9/} Allow the sections to remain in the stain for at least 1 minute (fig. 1e).
5. Wash the stained section in a dish containing 95-percent solution of ethyl or isopropyl alcohol. Washing and destaining normally requires only 10 to 20 seconds. No overstaining with safranin in step 4 is possible because excess stain can be removed by adding a few drops of HCl acid to this 95-percent alcohol solution.
6. Place the sections, one at a time, into a dish of fast green^{10/} and leave for 2 to 10 seconds.
7. Place the stained section in a dish of 95-percent solution of ethyl or isopropyl alcohol until no more stain washes off. This takes only 5 to 10 seconds. Woody tissues stain light red and the bark a dark purple or blue (fig. 1f).

^{9/} Safranin 0 staining is done with one part safranin 0 to 99 parts alcohol (50-percent solution).

^{10/} Fast green staining is done in a saturated solution of fast green in 95-percent alcohol solution. Make the staining solution at least 1 day before use.

8. Place the stained sections on a microscope slide and add enough 95-percent alcohol solution to prevent drying of the sections while the slide is being examined. A cover glass should be lowered carefully on the section. If it is not lowered gradually, there will be air bubbles trapped between the slide and cover glass, and this makes observation of wound-xylem areas difficult.
9. Examine the slide under a microscope. Look for wound-xylem areas in each union zone where a cambium connected the scion and the stock at the start of the 2d year after grafting. Incompatible grafts develop a wound in each zone. Determine how many grafts of each clone formed wound-xylem areas.
10. For each clone, add the number of grafts which died of early incompatibility (A-2 value) to the number of grafts which had wound xylem (B-9 value). Divide the sum by the test base number of grafts living after 4 months (A-1 value) and multiply the result by 100. The resulting value is the percentage of incompatibility shown by the tested clone.
11. At this stage, the orchardist should again exclude clones which are too incompatible to warrant grafting.

Equipment and Supplies

1. Ninety-five-percent solution of ethyl or isopropyl alcohol.
2. Vials or small jars for storing the grafts and alcohol fixative (corks or covers are needed).
3. A sharp knife or razor blades.
4. Six petri dishes or other small dishes.
5. Microscope capable of 100X magnification (a low-power dissecting scope capable of 10-30X magnification is a very helpful supplement but cannot replace the larger microscope).
6. Fast green stain.
7. Safranin O stain.
8. Tweezers.
9. Microscope slides and coverslips.

Research Note

FOREST AND RANGE EXPERIMENT STATION

U. S. DEPARTMENT OF AGRICULTURE • PORTLAND, OREGON

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GRASS-LEGUME MIXTURES FOR ROADSIDE SOIL STABILIZATION

by

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The construction of forest access roads often increases soil erosion and stream sedimentation. In steep terrain, road construction disturbs from 6 to 8 percent of the area, and the bare roadside slopes are especially vulnerable to erosion during the first few months following construction. Fredriksen^{1/} reported that although stream sediment content increased 250 times during the first rainstorms after road construction, sediment levels dropped almost to preconstruction levels after only 2 months.

To minimize soil movement, some sort of cover is needed on roadside slopes as soon after construction as possible. Unfortunately, establishment of natural vegetation is extremely slow on these sites because of low soil fertility and unfavorable microclimatic conditions. Realizing the importance of quick stabilization, the Forest Service initiated a roadside grass seeding program in western Oregon and Washington about 12 years ago. Selection of seed mixtures, fertilization treatments, and methods of application have been based on experience and recommendations of county agents and the Soil Conservation Service, U. S. Department of Agriculture. There has been no standardized approach within the Forest Service; rather, methods vary from Forest to Forest and even among Districts. Seeded mixtures often contain a legume--generally white Dutch clover (*Trifolium repens* L.). However, in some areas the legume has been omitted from the mixture because its

^{1/} Fredriksen [Fredriksen], R. L. Sedimentation after logging road construction in a small western Oregon watershed. U.S. Dep. Agr. Misc. Pub. 970: 56-59, illus. 1965.

high palatability resulted in deer concentrations on highly erodible slopes. The results of grass or grass-legume seedings are sometimes satisfactory. However, seeded areas are often not stabilized at all or erosion is only slowed temporarily. Some of the difficulties encountered include poor germination of seed, rolling of seed to the bottom of cut-and-fill slopes before germination, and deterioration of good grass stands after 2 or 3 years, all resulting in establishment of sparse stands which do not fully protect the site.

Despite the generally recognized seriousness of the problem, there has been very little formal research on roadside soil stabilization in the Pacific Northwest. Consequently, most available information is derived from experience and casual observation, rather than from controlled experimentation. Bethlahmy,^{2/} working on abandoned logging roads in the Cascade Range east of Portland, Oreg., found that application of 450 pounds per acre of a 6-10-4 fertilizer significantly aided establishment of a grass mixture. Raking following seeding also aided grass growth. Wollum^{3/} tested grass seeding as a control for roadbank erosion in the H. J. Andrews Experimental Forest. He found that, although a dense grass cover increased the amount of runoff, soil erosion was greatly reduced.

The Soil Conservation Service tests plant species for use in soil conservation planting. Most of the plant materials tested and recommendations issued by the Soil Conservation Service are aimed toward farm use. However, these recommendations include guidelines for planting severely eroded and subsoil areas, such as around dams or on ditch banks. Hafenrichter, Mullen, and Brown^{4/} have listed many of the grass and legume species that have been tested in the Pacific Northwest, the characteristics of each species, and the areas best suited for their growth.

The author wishes to acknowledge the splendid cooperation he has received from personnel of the Soil Conservation Service Plant Materials Center at Corvallis, Oreg. Robert S. MacLauchlan of that center provided valuable advice concerning design of the studies, suggested plant species for possible evaluation, and greatly aided in procurement of plant materials.

^{2/} Bethlahmy, Nedavia. Fertilizer helps establish grass seedings on abandoned logging roads. J. Forest. 58: 965-966, illus. 1960.

^{3/} Wollum, A. G. II. Grass seeding as a control for roadbank erosion. U.S. Forest Serv. Pacific Northwest Forest & Range Exp. Sta. Res. Note 218, 5 pp., illus. 1962.

^{4/} Hafenrichter, A. L., Mullen, Lowell A., and Brown, Robert L. Grasses and legumes for soil conservation in the Pacific Northwest. U.S. Dep. Agr. Misc. Pub. 678, 56 pp., illus. 1949.

This study is divided into two sections. The first describes a search for legume species suitable for inclusion in grass-legume mixtures. The second compares the performance of several grass-legume mixtures growing in roadside slope locations.

FIELD EVALUATION OF EIGHT LEGUME SPECIES

One means of improving growth and the stabilizing effects of roadside plantings is through selection of more suitable plant materials. Many species have already been tried, some of which proved to be well adapted. The search, however, should be a continuing one, because environments of the sites to be planted are tremendously varied. Moisture conditions range from wet to dry. Slopes vary in steepness and in the important factor of aspect. Soil fertility levels, dependent on parent material and quantity of surface soil present, are extremely variable.

In addition to the multiplicity of site factors, differing stabilization requirements also add to the complexity. To prevent surface erosion, a fast-growing, sod-forming grass is needed; but, on the other hand, mass movement prevention requires deep-rooted shrubs and trees. Therefore, well-suited plant species are needed which will thrive under a variety of site conditions and meet varied stabilization requirements.

An evaluation of roadside seedings on National Forest lands indicated that perhaps the inclusion of vigorous, fast-spreading legumes in the mixture might result in a denser and longer-lasting stand of vegetation. It was felt that the poor performance of seeded grasses a year or two after seeding might be partially attributed to low soil fertility and, especially, lack of available nitrogen. As previously mentioned, white Dutch clover is the only legume commonly used at the present time. Its performance is often unsatisfactory for several reasons. The clover is often restricted to only the more gentle slopes and, in some areas, its high palatability results in heavy deer use.

An exploratory study of the performance of eight legume species, growing on subsoils at moderate elevations in the Coast Ranges and western Cascades of Oregon, was initiated during the fall of 1964. This initial field screening was necessary because several of the species had never before been planted in comparable locations.

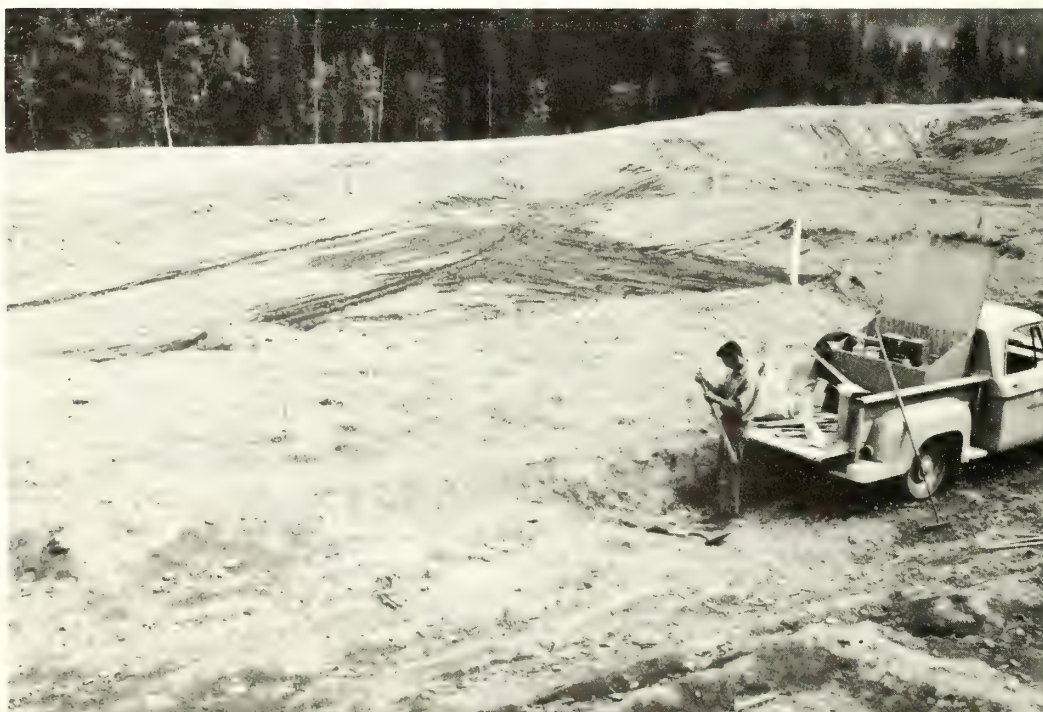
Methods

Legume planting plots are located near Divide Lookout in the Alsea District, Siuslaw National Forest (Coast Ranges), and at the edge of a borrow pit near Cougar Dam in the Blue River District, Willamette National Forest (western Cascades). Elevations are 1,700 feet and 1,200 feet, respectively. Both plot sites are essentially level and comprised solely of subsoil material (figs. 1 and 2). The Alsea plots



Figure 1.--General view of a portion of the fall-seeded legume plot near Divide Lookout, Alsea District, Siuslaw National Forest (2 years after seeding). Rows on the left are big trefoil. Note invading grasses and lupine.

Figure 2.--Spring legume plot immediately after seeding, near Cougar Dam, Blue River District, Willamette National Forest. Note the grass straw mulch.



are on an abandoned log landing where the exposed surface is comprised of subsoil of the Bohannon soil series mixed with large amounts of weathered Tyee sandstone. At the Blue River site, the exposed subsoil is a loamy alluvium mixed with a large quantity of water-worn gravels and cobbles (mostly andesite). At the time of planting, both plot locations had very little vegetation.

Plantings were made September 22 and 23, 1964, and April 27 through 29, 1965, at both locations. Species seeded in the fall included white Dutch clover, New Zealand white clover (*Trifolium repens* L.), wetland deervetch (big trefoil) (*Lotus uliginosus* Schkuhr.), birdsfoot deervetch (trefoil) (*Lotus corniculatus* L.), crownvetch (*Coronilla varia* L., "Emerald"), cicer milkvetch (*Astragalus cicer* L.), and flat peavine (pea) (*Lathyrus sylvestris* L.). Also, 20 transplants each of milkvetch, big trefoil, and bramble (perennial) vetch (*Vicia tenuifolia* L.) were set out at each site. In addition, 20 flat pea seedlings were planted in the Alsea plot. In the spring, the same seven legume species were again seeded, with the addition of perennial vetch. No transplants were set out in the spring.

Seeds were first mixed with a commercial inoculant, then sown in four 25-foot rows which were 30 inches apart. To aid in uniform distribution, the seed for each species was also mixed with 0.3 pound of rice hulls. Seed was sown by a push-type hand seeder (Planet Jr. Seeder). In the fall, transplants of each species were planted in individual rows 1 foot apart.

Soil tests for the two sites indicated the soils were deficient in nitrogen, phosphorus, and to a certain extent, potassium. Accordingly, 25 pounds of single superphosphate (19 percent P_2O_5), 6 pounds of ammonium nitrate (35 percent elemental N), and 5 pounds of muriate of potash were applied to both 25- by 80-foot plots. In addition, 200 pounds of lime was applied to the Alsea plots and one-half cup of lime per species (4 cups total) was applied with the seed at Blue River. Fertilization treatment was the same for both fall and spring plots.

After seeding, plots were mulched with approximately 200 pounds of oat straw for the fall planting and 200 pounds of grass straw in the spring.

Results

Performance of seeded legumes was evaluated 1 to 2 months after planting and in the fall, spring, and midsummer thereafter. Results are summarized in table 1. In most cases, legume growth showed little difference between fall and spring seeding.

1. *Big trefoil* (fig. 3). In all cases, this species germinated very well, and for the first 2 months, rows were extremely dense.

Table 1.--Performance of eight seeded legumes in the Coast Ranges (Alsea District)
and western Cascades (Blue River District) of Oregon

Species and time of seeding	Plot location	Germination and establishment	Density	General vigor	Maximum final height	Maximum final spread
					<u>Inches</u>	<u>Inches</u>
Big trefoil						
Fall	Alsea	Excellent	Moderately dense	Very good	10	20
Fall	Blue River	Excellent	Very scattered	Moderate	3	18
Spring	Alsea	Excellent	Moderately dense	Good	10	10
Spring	Blue River	Excellent	Scattered	Good	3	18
White Dutch clover						
Fall	Alsea	Excellent	Moderately dense	Poor	2	(1/)
Fall	Blue River	Excellent	Very scattered	Moderate	2	5
Spring	Alsea	Excellent	Scattered	Good	5	8
Spring	Blue River	Excellent	Very scattered	Poor	2	(1/)
New Zealand white clover						
Fall	Alsea	Excellent	Dense	Poor	2	(1/)
Fall	Blue River	Excellent	Scattered	Good	5	7
Spring	Alsea	Excellent	Scattered	Good	5	8
Spring	Blue River	Excellent	Scattered	Poor	2	5
Crownvetch						
Fall	Alsea	Good	None present	None present	0	0
Fall	Blue River	Excellent	Very scattered	Very poor	1	3
Spring	Alsea	Good	None present	None present	0	0
Spring	Blue River	Very good	None present	None present	0	0
Flat pea						
Fall	Alsea	Poor	Only 12 plants	Moderate	4	12
Fall	Blue River	Very poor	None present	None present	0	0
Spring	Alsea	None present	None present	None present	0	0
Spring	Blue River	Very poor	None present	None present	0	0
Birdsfoot trefoil						
Fall	Alsea	Good	Moderately dense	Good	11	15
Fall	Blue River	Good	Scattered	Good	8	12
Spring	Alsea	Excellent	Scattered	Very good	8	15
Spring	Blue River	Very good	Very scattered	Moderate	8	12
Cicer milkvetch						
Fall	Alsea	Fair	None present	None present	0	0
Fall	Blue River	Fair	Only 3 plants	Poor	--	--
Spring	Alsea	Fair	Only 4 plants	Poor	2-1/2	--
Spring	Blue River	Excellent	Scattered	Moderate	3	10
Perennial vetch						
Spring	Alsea	Good	Scattered	Good	3	3
Spring	Blue River	Excellent	Very scattered	Poor	3	(1/)

1/ Little.

Figure 3.--Fall-seeded big
trefoil plants 2 years
after seeding
(Alsea plot).



The smaller number of surviving plants on the Blue River plots was largely due to extensive winter mortality, probably caused by frost heaving. The remaining plants, however, were at least moderately vigorous, set seed, and showed considerable spread. Big trefoil transplants survived well at both plot sites and showed vigorous growth. Rate of growth was considerably greater at the Alsea plot where, 2 years after transplanting, maximum spread was approximately 3-1/2 feet.

In summary, big trefoil appears well suited to the Coast Ranges site. Its performance near Blue River indicates that once the plants become well established, growth is satisfactory. The principal problem under these climatic conditions is one of high winter mortality.

2. *White Dutch clover*. The species germinated very well in all plantings. With the exception of the fall planting at the Alsea plot, plant density decreased greatly during the first growing season. This was probably caused by decreasing soil nutrient availability coupled with low soil moisture levels. The low vigor of the clover in the fall Alsea plot was perhaps partially due to crowding in the dense rows.

It appears that white Dutch clover is at least moderately well adapted to both plot locations, although it is subject to considerable growing-season mortality and exhibits variable vigor.

3. *New Zealand white clover* (fig. 4). This variety performed in a manner almost identical to white Dutch clover in the Alsea plots. In the Blue River plots, it showed slightly better growth than white Dutch clover. Therefore, New Zealand white clover may prove to be better adapted than white Dutch clover to conditions in the western Cascades.



Figure 4.--Spring-seeded New Zealand white clover plants 1-1/2 years after seeding (Alsea plot).

4. *Crownvetch*. Although this species germinated fairly well, mortality was high during both the winter and growing seasons. As a result, no plants were found after one or two growing seasons on three out of the four plots. Where it did survive, vigor was very low.

Crownvetch does not appear to be suitable for planting in this area.

5. *Flat pea*. This species germinated poorly at all plots. Flat pea seeds have very hard seedcoats and, therefore, are difficult to propagate from seed. However, transplants placed in the Alsea plot did extremely well (fig. 5). After two growing seasons, the plants were thriving and had a maximum spread of about 5 feet.

Apparently flat pea is adapted to our climatic conditions, but transplanting is necessary to gain successful establishment.

6. *Birdsfoot trefoil*. Germination and initial establishment of this species was good to excellent. Considerable thinning of the rows



Figure 5.--Transplant area in the Alsea plot 2 years after planting. Note luxuriant growth. Rows, difficult to distinguish because of lateral spread, are from left to right: cicer milkvetch, perennial vetch, big trefoil, and flat pea.

resulted from frost-heaving mortality in the winter. Surviving plants, however, generally showed good vigor, and a large proportion flowered and set seed.

Birdsfoot trefoil appears to be at least moderately well adapted to site conditions at both plot locations.

7. *Cicer milkvetch*. This species grew poorly from seed on all plots except the spring plot at Blue River. Here the seedlings showed moderate vigor and were beginning to spread. Survival of transplanted cicer milkvetch was poor at Blue River but good at the Alsea plot. However, even on the Alsea plot, growth was unsatisfactory and the transplants tended to be spindly and chlorotic.

These results indicate that cicer milkvetch is not suited to the climatic and soil conditions of the Coast Ranges and western Cascades.

8. *Perennial vetch*. This species was seeded only in the spring. Its performance at Blue River was poor. However, it grew fairly well on the Alsea plot and showed good vigor even though the plants tended to be small. Perennial vetch transplants also grew poorly at Blue River despite fairly good survival. Transplants on the Alsea plot generally grew very well to a maximum spread of about 2-1/2 feet (fig. 5).

Perennial vetch shows some promise for use in the Coast Ranges but appears to be poorly adapted to conditions in the western Cascades.

Discussion

This exploratory study demonstrated that field evaluation of individual cover plants is a practical means of screening candidate species. There is a need to expand this approach to include many additional species holding promise for soil stabilization purposes. The search for suitable species must be continuous if the maximum effectiveness in soil stabilization is desired. Woody as well as herbaceous plants should be considered. Certain native species also show considerable promise. For example, at the Alsea site, a native lupine (*Lupinus* sp. L.) invaded the fall-seeded plot and grew well despite low soil fertility. Methods for propagating this species should be worked out and consideration given to including it in some grass-legume mixtures in the Oregon Coast Ranges.

On the basis of these results, big trefoil and New Zealand white clover were selected for inclusion in experimental grass-legume mixtures to be seeded in the western Cascades near the Blue River legume plot. The performance of these mixtures is described in the section which follows.

ROADSIDE PLOT EXPERIMENTS

To evaluate the performance of several grass-legume mixtures, a field plot experiment was initiated in the fall of 1965. Plots were located in the H. J. Andrews Experimental Forest (Blue River District, Willamette National Forest).

Methods

Plots were established at a backslope site (spur road No. L440, 2,450-foot elevation) and on side-cast material just below the road to watershed 1 landing (1,500-foot elevation). At the backslope site, the road was about 5 years old. At the time of planting, the slope was almost devoid of vegetation and obviously was eroding. The soil is a Regosol derived from reddish tuffs and breccias and is classified within the Frissell series. The backslope was approximately 1:1 and had a south aspect.

The side-cast plots were located along a road which was constructed about 4 years prior to this experiment. This steep, west-facing slope had very little vegetation; grasses and herbs present were removed before the plots were installed. The soil at this location is similar to that at the backslope site except for the presence of a considerable number of andesite stones.

A randomized-block experimental design was followed. Five grass-legume mixtures plus a control were replicated twice at both the back-slope and side-cast locations for a total of 12 plots at each site. Plots were 6 feet wide, extended up and down slope for the entire length of the backslope, and were 25 feet long on the side-cast slope. Since the plots were contiguous, the total length along the road was 72 feet.

Treatments applied were as follows:

1. Control--bare soil only.
2. Straw mulch only--2 tons per acre.
3. Seeded with Blue River District mixture of:
 - colonial bentgrass (*Agrostis tenuis* Sibth.)--6.25 pounds per acre
 - creeping red fescue (*Festuca rubra* L.)--5.00 pounds per acre
 - perennial rye grass (*Lolium perenne* L.)--3.75 pounds per acre
 - alta (tall) fescue (*Festuca arundinacea* (Schreb.) Wimm.)--8.75 pounds per acre
 - white Dutch clover--1.25 pounds per acre.
4. Seeded with Oregon Highway Department mixture of:
 - creeping red fescue--18 pounds per acre
 - chewings fescue (*Festuca rubra* var. *commutata* Gaud.)--12 pounds per acre
 - perennial rye grass--4 pounds per acre
 - white Dutch clover--6 pounds per acre
 - straw mulch--2 tons per acre.
5. Seeded with experimental mixture No. 1 of:
 - tall fescue--20 pounds per acre
 - Italian rye grass (*Lolium multiflorum* Lam.)--8 pounds per acre
 - creeping red fescue--3 pounds per acre
 - New Zealand white clover--2 pounds per acre
 - big trefoil--2 pounds per acre
 - straw mulch--2 tons per acre.
6. Seeded with experimental mixture No. 2 of:
 - orchard grass (*Dactylis glomerata* L.)--20 pounds per acre
 - Italian rye grass--8 pounds per acre
 - creeping red fescue--8 pounds per acre
 - colonial bent grass--3 pounds per acre

New Zealand white clover--2 pounds per acre
big trefoil--2 pounds per acre
straw mulch--2 tons per acre.

In addition, all treatments, with the exception of the control, received a blanket application of ammonium phosphate (16-20-0) at the rate of 400 pounds per acre both in the fall and the following spring.

Plot location within each block was randomized. Seeding, fertilization, and mulching were carried out on September 21 and 22, 1965.

Soil movement on the plots was monitored by periodic measurements of the distance between points on a stretched wire cable and the mineral soil surface directly beneath. The measurement was accomplished with a steel tape and attached plumb bob held next to the profile cable at the appropriate point. Three transects, 1 foot apart and extending up and down slope in the central 2-foot strip, were measured in each plot. Fifteen measurements were made along each transect at 1-foot intervals. The first measurement was made 1 foot below the upper boundary of the plot. Therefore, the elevation of the upper 15 feet of slope was measured.

Vegetative cover on each plot was ocularly estimated at frequent intervals. In addition, species composition was noted and recorded for each plot.

Results

A satisfactory grass-legume mixture must provide fast initial growth and quick cover if soil movement is to be minimized. Observations made approximately 3 months after seeding disclosed that three out of the four mixtures seeded in the present study provided satisfactory and equivalent cover during these first critical months (fig. 6). The Oregon Highway Department mixture and experimental mixtures 1 and 2 provided slightly more than 50-percent cover at the end of 3 months on side-cast plots and about 35- to 50-percent cover on the backslope plots. However, after the same period, plots seeded with the Blue River District mixture had only 30-percent cover at the side-cast location and between 15- and 20-percent on the backslope. The difference in cover was apparently caused largely by the lack of straw mulch in the Blue River mixture treatment. The mulch applied with the Oregon Highway Department mixture and the two experimental mixtures appeared to greatly reduce downslope seed movement and thus insure even distribution of vegetation. The distribution of grass cover on the Blue River plots indicated considerable downslope movement of seed; the steepest portions of the slopes were invariably almost devoid of cover. An additional advantage of straw mulch, which may have had some influence here, is its ability to protect newly germinated seedlings from frost-heaving damage.

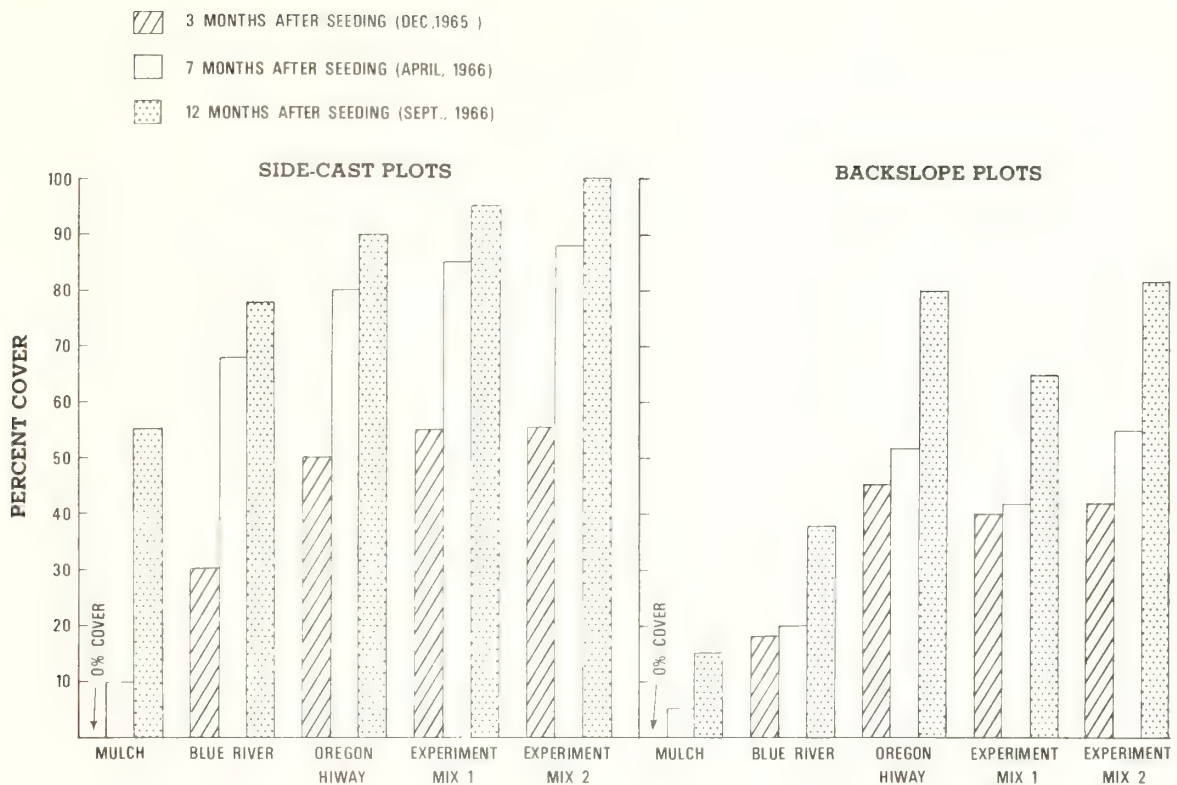


Figure 6.--Vegetative cover on roadside plots 3, 7, and 12 months after seeding.

The Italian rye grass in experimental mixtures 1 and 2 clearly outperformed the perennial rye grass in the Oregon Highway Department and Blue River District mixtures during the first 3 months after seeding. At the end of this period, maximum height of Italian rye grass was 10 inches at the side-cast location and 4 inches at the backslope site. Corresponding figures for perennial rye grass were only 3 and 2 inches. Because of the need for quick cover, the unusually rapid development of Italian rye grass commends it for inclusion in grass-legume mixtures for roadside planting. These results suggest that perhaps it should be substituted for the perennial rye grass which is generally included.

Examination of the plots in April, 7 months after establishment, disclosed a considerable increase in cover on the side-cast plots but a more modest increase on the higher elevation backslope plots (figs. 6, 7, and 8). Gaps on the steeper portions of the Blue River District plots persisted and cover continued to be spotty, especially at the backslope location (fig. 9). Maximum grass height was approximately 11 inches on the Oregon Highway Department and experimental mixture plots (fig. 10), but was only 6 inches on the Blue River mixture plots.

The difference is apparently once again tied to the absence of straw mulch on Blue River mixture plots.



Figure 7.--Side-cast plots 7 months after seeding. The cable for measuring the slope profile is stretched between the channel irons.



Figure 8.--Backslope plots 7 months after seeding.

**Figure 9.--Blue River District mixture
on backslope 7 months after
seeding. Note absence of cover
on the steep, middle portion of
the slope.**



**Figure 10.--Experimental mixture No. 2
on backslope 7 months after seeding.**



At the end of a full year, all seeded plots at the side-cast location had a very satisfactory grass stand. Total cover ranged from a little less than 80 to 100 percent (fig. 6). Even the plots which were not seeded but only mulched were covered with a moderately dense stand of vegetation--largely grass. Vegetative cover was lower on the back-slope plots but generally dense except for small gaps, usually at steep midslope locations (fig. 11). The only exceptions were the Blue River mixture plots, where only about one-third of the total plot area was covered by grass. The other seeded plots were at least two-thirds covered by the end of the year (fig. 6).

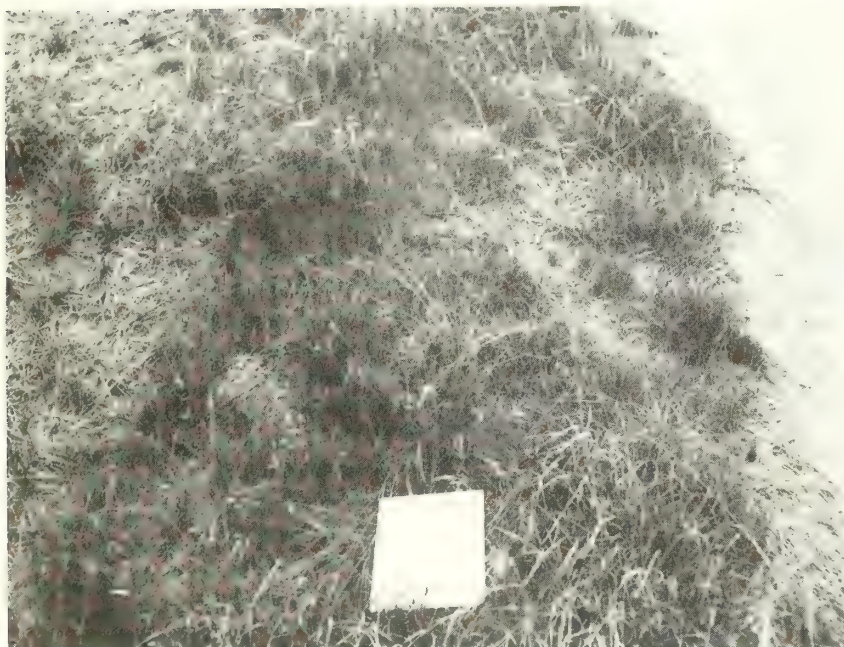


Figure 11.--Experimental mixture No. 2 on backslope 12 months after seeding.

Species present on seeded plots after 3 months were almost exclusively the ryegrasses--either perennial or Italian--and white clover seedlings. Inspection the following spring, 7 months after seeding, revealed that vigorous white clover plants still made up a significant portion of the total stand. However, after another 5 months, it was difficult to find even a single clover plant on most of the plots. Apparently the summer dry period had resulted in virtually 100-percent clover mortality. Big trefoil, included in both experimental mixtures, was never found on either the backslope or side-cast plots.

At the end of 1 year (September 1965 to September 1966), vegetative composition of seeded plots was as follows:

1. *Blue River District mixture*. Dominantly colonial bentgrass, well-distributed perennial ryegrass, and very small amounts of creeping red fescue.
2. *Oregon Highway Department mixture*. Dominantly creeping red and/or chewings fescue, well-distributed perennial ryegrass, and considerable colonial bentgrass, especially on the side-cast plots.
3. *Experimental mixture No. 1*. On most plots, colonial bentgrass and Italian ryegrass were codominant, with only scattered tall fescue and creeping red fescue.
4. *Experimental mixture No. 2*. On side-cast plots, ryegrass was dominant followed by colonial bentgrass; the reverse was true on the backslope plots. At both locations, there were only scattered amounts of orchard grass and creeping red fescue.

First-year soil movement results for the backslope plots are presented in table 2. It was not possible to obtain similar figures for the side-cast plots because several posts necessary for supporting the measuring cable were accidentally destroyed. Analysis of variance

Table 2.--Average soil loss or gain on the backslope plots for the period November 1965 to November 1966

Treatment	Block 1	Block 2	Treatment mean
----- <u>Inches</u> -----			
Control (bare)	-0.23	-0.44	-0.34
Mulch only	+0.13	-0.14	0.00
Blue River District mixture	+0.05	+0.14	+0.10
Oregon Highway Department mixture	-0.13	-0.04	-0.08
Experimental mixture 1	+0.11	+0.10	+0.10
Experimental mixture 2	+0.14	-0.01	+0.06

of the data in table 2 indicated a significant treatment effect at the 5-percent level. The Duncan multiple range test showed the treatment mean for the control was the only one which differed significantly from the other five means. In other words, it is concluded that the mulch, Blue River District mixture, Oregon Highway Department mixture, and experimental mixtures 1 and 2 treatments are equally effective in curtailing soil movement on these plots.

The apparent slight increase in soil depth measured on Blue River and experimental mixture plots is hard to explain. Perhaps at least a portion of this increase may be due to frost heaving. However, there was reason to believe that there was a small amount of actual deposition of soil on the slope. Undoubtedly, some soil material broke loose from the top of the cut, part of which may have come to rest further down the slope where it was measured.

The contrasting results obtained in the two mulch-only plots (table 2) are also difficult to explain. Throughout the year, the two plots seemed similar with respect to the cover of both mulch and the small amount of volunteer vegetation which appeared. The observed difference in soil movement on the two plots may be partially attributable to plot location.

Discussion

Although all four grass-legume mixtures seeded in this study produced at least moderately dense stands and afforded considerable soil protection, they failed to meet one objective--that of providing a thrifty legume component. The two varieties of white clover apparently succumbed as a result of low soil moisture levels during the summer. Big trefoil, on the other hand, either failed to germinate or the newly germinated seedlings all died during the winter. Even though results of this exploratory study must be considered tentative, they do suggest the need for including better suited legume species in the mixture.

Results reported here have underscored the importance of other cultural practices in addition to the composition of the seed mixture. The consistent superior performance of mulched plots indicates that, on critical slopes, straw mulch may be well worth its rather high cost of application. Newly constructed road slopes may benefit even more from mulch than did the older and more stable slopes used in the present study. Probably a good portion of the success in obtaining dense stands of grass may be credited to ample fertilization both at the time of seeding and the following spring. The question now is, how long will this vegetative cover maintain itself without any further nutrient additions? Research is needed to determine whether periodic refertilization is economically justifiable.

Results for the backslope plots show that all five treatments were about equally effective in curtailing erosion. It is a little surprising that even the Blue River plots with only about 35-percent plant cover showed no erosion and, in fact, showed a slight increase in soil depth. Apparently, some gaps in the grass cover do not substantially decrease its effectiveness in preventing erosion, at least on roadside slopes which are several years old. Rates of erosion along newly constructed roads would be expected to be considerably greater than those measured in the present study.

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Research Note

FOREST AND RANGE EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE • PORTLAND, OREGON

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TWO-YEAR RESULTS OF A WEST-EAST TRANSECT-PROVENANCE TEST OF DOUGLAS-FIR IN OREGON

by Frank Sorensen
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INTRODUCTION

This 2-year exploratory seed source test was started primarily to identify breaks in response patterns of Douglas-fir along a west-east transect, so that these breaks could be characterized in more detail later. As planting and the tree improvement program expand in the Douglas-fir region, it becomes more and more important that such characterization be done, and it is hoped that exploratory studies such as this can give direction to the effort. A transect running through Corvallis, Oregon, was an appropriate place to start in this case since parts of this transect have been investigated in previous genetic and phenology studies (Irgens-Moller 1957, 1967; Silen 1963; Silen and Krueger 1962).

MATERIALS AND METHODS

Single-tree seed collections were made at eight locations along a west-east transect across Oregon from the Coast Ranges into southwestern Idaho. Information on sources is given in table 1. Seeds were germinated under standard conditions^{1/} in a commercial germinator. After germination they were sown at 3- by 3-inch spacing

^{1/} Conditions used at Seed Testing Laboratory at Oregon State University.

Table 1.--Description of sources of Douglas-fir seeds along a west-east transect across central Oregon

Seed source	Latitude	Longitude	Elevation	Number of trees in collection	Geographic description
			<u>Feet</u>		
Burnt Woods	44° 35'	123° 40'	700	8	West side, Coast Ranges
Corvallis	44° 40'	123° 15'	400	6	East foothills, Coast Ranges
Lacomb	44° 35'	122° 40'	900	6	West foothills, Cascades
Lava Lakes	44° 30'	122° 00'	3,500	(1/)	High Cascades-- west side of divide
Santiam Pass	44° 25'	121° 50'	4,400	6	High Cascades-- just east of divide
Metolius	44° 30'	121° 40'	3,000	6	East Cascades
Malheur	43° 50'	119° 50'	5,400	2	Ochoco Mountains-- eastern Oregon
Owyhee	43° 10'	116° 45'	5,800	4	Owyhee Mountains-- southeastern Idaho

^{1/} Collected by M. Newton and J. Zavitkovski of Oregon State University; all other lots collected by author. No record made of exact number, but estimated to be three to five.

in randomized complete block design in Chehalis loam soil under 40-percent shade in cold frames at Corvallis. Seeding in cold frames was started May 15. Shading was removed at end of the first growing season. The eight sources were represented by six 10-tree rows, one row per block. The following measurements and observations were made on seeds and seedlings. Counts or measurements on all traits except seed weight were subjected to analysis of variance.

1. Seed was carefully cleaned before weighing. Weight of 100 seed was calculated from an approximately 200-seed sample which was germinated for outplanting.
2. Cotyledon numbers were counted.

3. Seedlings were observed Friday morning of each week through the summer of first growing season. Date of first appearance of terminal bud was recorded. If the seedling broke bud again, date of first appearance of final bud was recorded. The week of July 5, 1965, was treated as week 1 and subsequent weeks as 2, 3, etc.
4. Height of the epicotyl to base of terminal bud was measured at end of the first growing season.
5. Seedlings were observed Monday, Wednesday, and Friday of each week during period of bud burst in spring of second growing season. Date when needles of terminal bud could first be observed through parting scales was recorded. April 1 was treated as day 1.
6. Total seedling height to base of terminal bud was measured at end of the second growing season.

Precipitation and temperature records were obtained for weather stations nearest to the seed collection points. Some of these weather stations collected only small amounts of data, so only average annual and average July-August precipitation and average January and July temperatures were extracted for comparison with seed source performance. Locations of weather stations are given in table 2.

All analyses of variance except that of average date of bud burst were made on transformed data--square root transformation for cotyledon numbers and $\log_{10}$ transformation for other observations. Averages listed in table 3 are reconverted from transformed data. Differences between individual means were established with a Tukey test and these differences are also listed in table 3.

RESULTS

Results of observations of seedlings are listed in table 3. Weather records for weather stations near points of seed origin are listed in table 2. Based on height growth during the first 2 years and date of bud set the 1st year, the eight sources separate into three rather distinct groups. Three low-elevation sources spanning the Coast Ranges and foothills of the Cascades make up one group, three sources from high elevation in the Cascades make up a second, and two sources from eastern Oregon and southwestern Idaho constitute the third.

Table 2.--Location of weather stations nearest to seed collection points, some precipitation and temperature averages for the stations and their corresponding seed sources

Station	Latitude	Longitude	Altitude	Average precipitation		Average temperature		Corresponding seed source
				Annual	July-August	January	July	
----- <u>Inches</u> ----- -- <u>Degrees F.</u> ---								
			<u>Feet</u>					
Summit	44° 38'	123° 35'	750	66	1.2	(<u>1</u> /)	(<u>1</u> /)	Burnt Woods
Corvallis	44° 38'	123° 12'	225	38	.7	39.4	66.6	Corvallis
Cascadia	44° 24'	122° 29'	850	61	1.4	37.2	65.3	Lacomb
Santiam Pass	44° 25'	121° 52'	4,750	<u>2</u> /91	<u>2</u> /3.0	<u>2</u> /29.5	<u>2</u> /56.1	Lava Lakes, Santiam Pass
Sisters	44° 17'	121° 32'	3,180	13	<u>3</u> /1.0	30.9	62.3	Metolius
Squaw Butte	43° 19'	119° 41'	4,675	12	.8	24.6	66.5	Malheur, Owyhee

1/ Record not kept.

2/ Figure based on 3 to 5 years of records.

3/ Record not kept at Sisters. Used record from Bend Station at 44°14' N., 121°19' W., elevation 3,500 feet.

Table 3.--Comparison of Douglas-fir seedlings of eight seed sources along a west-east transect across Oregon based on early growth characteristics

Seed source	Average seed weight	Average cotyledon number	Average date of bud set, 1st year ^{1/}	Average epicotyl height, 1st year	Average date of bud burst, 2d year ^{2/}	Average height, 2d year
	-- Grams per 100 seeds --			----- Mm.-----		-- Mm.--
Burnt Woods	1.17	6.65 a ^{3/}	11.6 a ^{3/}	40.9 a ^{3/}	19.9 a ^{3/}	267 a ^{3/}
Corvallis	1.18	7.10 ab	9.6 ab	32.8 ab	3.2 b	234 a
Lacomb	1.10	6.77 ab	10.5 a	38.8 ab	8.3 c	260 a
Lava Lakes	1.02	7.35 c	6.9 c	17.8 c	6.9 bc	136 b
Santiam Pass	1.07	6.19 a	7.5 bc	19.2 c	8.4 c	131 b
Metolius	1.34	7.11 abc	7.4 bc	23.7 bc	5.2 bc	166 b
Malheur	1.57	8.00 d	1.6 d	5.6 d	7.1 bc	78 c
Owyhee	1.70	7.78 cd	4/1.0 d	4.2 d	5.4 bc	65 c

^{1/} Number of weeks after July 1.

^{2/} Number of days after April 1.

^{3/} Tukey tests have indicated that any means with a common letter are not significantly different at the 5-percent level.

^{4/} Average date should probably be earlier than first week of July. Observations started this week, but majority of Owyhee seedlings had already set bud. Remainder set bud this week.

Comparison of dates of bud burst in the second spring indicates a further differentiation among sources of the first group--Corvallis seedlings burst bud earlier and coastal seedlings (Burnt Woods) considerably later than any other source.

DISCUSSION

As already reported by Irgens-Moller (1957, 1967), the most distinct differences in seedling phenology are found between sources from east foothills of the Coast Ranges and from west side of the Willamette Valley. The most easterly of the coastal sources tested by Irgens-Moller is separated from the Corvallis source by only about 11 air-miles and 400-foot elevation, yet their average dates of bud burst are very different. It is assumed that this sharp change in phenology of Douglas-fir seedlings over such a short distance is in response to a fairly sharp break in oceanic influence. For example, it is known that average precipitations at Corvallis and the nearest station to the west, Summit (about 14 miles away), differ greatly (table 2). What is not known, however, is just how sharp climatic and phenologic transitions are, just where they occur, and whether environmental factors other than climatic are involved.

If transition zone or "break" is based solely on presence or absence of a certain oceanic influence, it probably weaves an irregular pattern north and south along east slopes of the Coast Ranges, influenced more perhaps by hills to the west of it than by any absolute altitude or distance from the coast. Locating of a line along the "break" for seed zone or tree improvement purposes, then, would not be a matter of following any particular topographic feature, such as a ridge, but rather of finding some method of estimating penetration inland of oceanic influence.

A second interesting east-side behavioral pattern also occurs on east slopes of the Cascades. Both weather data in table 2 and personal observations at the eastern fringe of Douglas-fir in the Cascades (Metolius source) indicate that growing conditions there differ considerably from those found in the high Cascades to the west and are probably more like eastern Oregon conditions. Yet, seedling phenology and growth appear, on the contrary, to be much more typical of high Cascades seedlings than of inland seedlings (table 3). This again implies that certain important adaptive changes in Douglas-fir of western Oregon may be found to occur at quite a distance from a distinct geographic feature, such as crest of a mountain range.

The third and most expected break in both weather patterns and seedling growth habits was between low-and high-elevation sources from the Cascades. The gap between sampled elevations was large, almost 2,500 feet, and not much can be said about the nature of the elevational cline until more sampling is done.

Sweet (1965) noted that there was little relation between average date of terminal bud burst of a number of widely scattered coastal Douglas-fir provenances and climate of seed source when the plants were grown in New Zealand. When we compare the three seed sources which originated near major weather stations, the same can be said for the seedlings raised in Corvallis. That is, average seedlings from Corvallis, Lacombe, and Metolius burst bud April 3, 8, and 5, respectively, when grown in Corvallis (table 3). Average dates of last killing spring frost, as recorded at weather stations near Corvallis, Lacombe, and Metolius, were April 12, May 3, and June 17, respectively; average lengths of frost-free season were 202, 163, and 62 days. Thus, it appears that inherent time of initiation of spring growth in Douglas-fir has not been determined solely, or even to a large degree, by selection pressures associated with frost-free period. This relationship warrants further investigation.

Squillace and Silen (1962) found that height growth of ponderosa pine progenies from seed sources throughout its range in Western United States was strongly correlated with moisture distribution expressed by September through June precipitation as percent of annual precipitation. The same relationship was tested using more limited area sampled in this test and again found to be quite close ($r = 0.65$, $n = 8$), though not significant. Metolius source was furthest outside the general pattern, and when it was removed from the analysis, the relationship improved ($r = 0.83$, $n = 7$) and reached significance ($p < 0.05$). This further emphasizes the uniqueness of the Metolius seedlings in that, at Corvallis, they develop much like high Cascades seedlings, although the environment in which they evolved appears quite different from high Cascades.

CONCLUSION

Important and rather sharp transitions in seedling growth habit appear to be associated with eastern slopes of Coast and Cascade Ranges in the Pacific Northwest. If it is desirable to locate and characterize these transition zones for either seed collection or research purposes, present exploratory results indicate that quite intensive sampling of both environment and Douglas-fir may be necessary.

SUMMARY

Seed from eight sources of Douglas-fir along a west-east transect across Oregon were grown through 2 years of age in a nursery bed near Corvallis, Oregon. Based on height growth and date of 1st-year bud set, sources can be separated into three groups with considerable similarity within groups and striking differences between them. Relationships between growth patterns and climatic and topographic variables, and the implications of these relationships to further studies in coastal Douglas-fir, are discussed.

REFERENCES

Irgens-Moller, Helge.

1957. Ecotypic response to temperature and photoperiod in Douglas-fir. *Forest Sci.* 3: 79-83, illus.

-
1967. Patterns of height growth initiation and cessation in Douglas-fir. *Silvae Genet.* 16(2): 56-58.

Silen, Roy R.

1963. Effect of altitude on factors of pollen contamination of Douglas-fir seed orchards. *J. Forest.* 61: 281-283, illus.

and Krueger, Kenneth W.

1962. Does rainy weather influence seed set of Douglas-fir? *J. Forest.* 60: 242-244, illus.

Squillace, A. E., and Silen, Roy R.

1962. Racial variation in ponderosa pine. *Forest Sci. Monogr.* 2, 27 pp., illus.

Sweet, G. B.

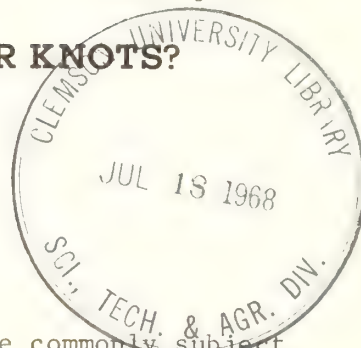
1965. Provenance differences in Pacific Coast Douglas fir. *Silvae Genet.* 14: 46-56.

PNW-73

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SHOULD LOG SCALE BE REDUCED FOR KNOTS?

by
Jack Levitan ^{1/}

**INTRODUCTION**

Logs with numerous large knots or limb stubs are commonly subject to a reduction in their net scaled board-foot volumes. This so-called rough cut reduction is made by the scaler to compensate for an expected loss in the quantity, and/or quality, of lumber produced from these knotty or "rough" logs. The validity of this roughness deduction has often been questioned.

The following rough-cut rule is followed by several log scaling and grading bureaus in the Pacific Northwest:^{2/} "Any logs so rough that the side cuts will not produce Standard or Better lumber shall have a deduction in scale of a sufficient amount to eliminate the Utility lumber in squaring up the log. This rule is to be applied only to extremely rough logs or especially knotty tops, and does not imply deductions on sound, tight-knotted logs."

With information from four sawmill yield studies, lumber recoveries from rough Douglas-fir logs were compared with recoveries from other Douglas-fir logs to see what differences in yield and value might actually exist. The recovery data were developed during a series of studies conducted in 1964 to 1966 by the Timber Quality Research Project,

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^{2/} Puget Sound, Grays Harbor, Southern Oregon, and Northern California Log Scaling and Grading Bureaus. Official log scaling and grading rules. 41 pp. 1966.

Pacific Northwest Forest and Range Experiment Station, U.S. Forest Service, in cooperation with private industry to test and revise coast Douglas-fir log grades. The mills concerned were U.S. Plywood, Mapleton, Oreg.; J. F. Sharp & Co., Yreka, Calif.; U.S. Plywood, Anderson, Calif.; and Timber Products Co., Medford, Oreg.

METHODS USED

A comparison was made of rough and "smooth" logs with respect to their lumber yield and value. All boards sawn from each log were marked by a log identification number. Boards were tallied according to log number, grade, and size so that recovery volume and dollar value of lumber produced could be related to log-scale volume and other log characteristics. Lumber grading was done by Western Wood Products Association or West Coast Lumber Inspection Bureau graders; lumber tallies were made by U.S. Forest Service and other U.S. Government personnel.

Sample Selection

From the scale records for each mill study, a sample of rough and smooth logs was selected. Rough logs were those in each study having no scale deductions except for roughness. The smooth logs, selected for comparison, were only those logs scaled as entirely sound. All logs used for volume recovery comparisons were either No. 2 or No. 3 sawmill grade.^{3/} Only No. 3 sawmill logs were used for dollar value comparisons because most rough logs fell in that grade. Log lengths varied from 8 to 26 feet with an average of approximately 16 feet. Diameters ranged from 6 to 42 inches. Table 1 shows a comparison of the number and diameter range of each sample.

Scaling

Scaling followed the National Forest Log Scaling Handbook,^{4/} using the Scribner Decimal C scale rule and providing for a diameter reduction for roughness. An experienced Bureau of Land Management scaler scaled all logs. Scaling of rough logs for this investigation was fairly representative of common practice, where variations in determination of roughness are introduced by reliance on human judgment rather than quantitative factors.

^{3/} U.S. Forest Service grading rules.

^{4/} U.S. Forest Service. National Forest log scaling handbook. FSH 2443.71, 193 pp., illus. 1963.

U.S. Forest Service. National Forest log scaling handbook, R-6 supplement No. 1 to FSH 2443.71 for west side scaling. 45 pp., illus. 1965.

Table 1.--Size of rough and smooth log samples

SIZE OF SAMPLES USED IN VOLUME-RECOVERY DETERMINATIONS

Mill study	Number of logs in sample		Diameter range (inches)	
	Rough	Smooth	Rough	Smooth
Mapleton	28	138	6-30	6-37
Yreka	41	322	8-38	7-42
Anderson	60	421	8-39	7-41
Medford	26	245	7-25	6-42

SIZE OF SAMPLES USED IN DOLLAR-VALUE DETERMINATIONS

Mapleton	26	58	6-30	6-29
Yreka	28	107	8-38	7-42
Anderson	60	239	8-39	7-36
Medford	26	115	7-25	6-31

The scale used in determining recovery by logs was based on log lengths as sawn on the headrig rather than woods-length logs. The use of the shorter sawmill lengths tends to reduce the variation in recovery in each log-diameter class and provides a better chance for large knots to affect lumber volume under the slab portion of the log because the effects of taper are reduced.

Analysis of Data

Data from each study were treated separately to avoid introducing possible bias attributable to unlike populations.

Volume recoveries by 1-inch diameter classes were computed by dividing lumber tally per log by gross scale and expressing the quotient as percentage. The regression of percent recovery on diameter, expressed as a first- or second-degree polynomial, was fitted by least squares.^{5/}

^{5/} First-degree curves were used where second-degree curves were not significant.

Dollar values per thousand board feet by 1-inch classes were obtained by dividing log values in dollars by gross scale for each class. These values were also analyzed by fitting first-or second-degree curves to the data and testing differences between fitted curves. The log values are based on average industry lumber prices for 1963.

RESULTS AND DISCUSSION

Volume Recovery

Comparisons between rough and smooth logs for each mill study are shown graphically in figures 1 through 4. In two cases (Mapleton and Yreka), the curves comparing rough with smooth log volume recovery are different in that rough logs below approximately 20 inches in scaling diameter produced higher volumes of sawn lumber than smooth logs of like scaling diameters, whereas above this approximate 20-inch mark, smooth logs produced higher volumes than rough logs.^{6/} In the other two cases (Anderson and Medford), no significant difference between rough and smooth log recoveries can be seen for like scaling diameters. However, the tendency for small-diameter logs to show higher volume recoveries for the rough logs is still apparent, although less marked. The rough log recovery curve for the Medford study indicates lower volumes for rough logs over 14 inches in diameter, although the mean volumes for rough and smooth logs are not significantly different. In the Anderson study, rough logs showed higher, but not significantly higher, recoveries for all diameters.

For all four studies, there was a tendency for small rough logs to produce more volume than smooth logs of like diameters. However, where logs of larger diameters were concerned, three of four comparisons showed a tendency for rough logs to produce less volume than smooth logs.

Recovery data for individual logs reveal two factors that seem to govern the differences in volume recovery between rough and smooth logs: log taper and the presence of dead branch stubs larger than 2 and 3 inches in diameter. Live knots, regardless of size, showed no appreciable effect on log volume recovery since most occurred on the smaller rough logs where recoveries were proportionally the highest. Rough logs less than 20 inches in diameter produced more volume than smooth logs of like diameters because of their much greater average taper and correspondingly larger amount of usable wood lying outside their scaled diameters.

^{6/} In both cases, the rough vs. smooth curves exhibited significant differences in slope at the 1-percent level of probability.

Figure 1.--Recoveries for smooth and rough logs by diameters, in percent of gross log scale. Data from Mapleton mill study, 1964.

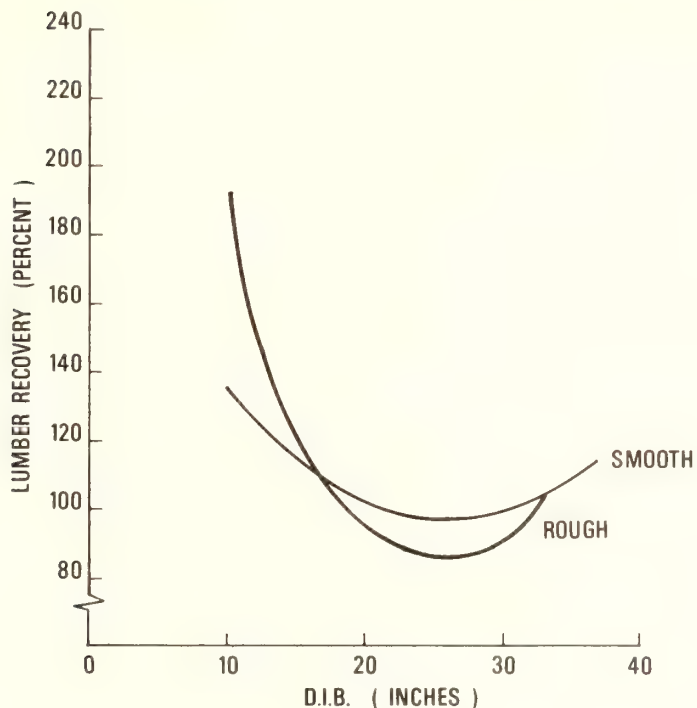


Figure 2.--Recoveries for smooth and rough logs by diameters, in percent of gross log scale. Data from Yreka mill study, 1965.

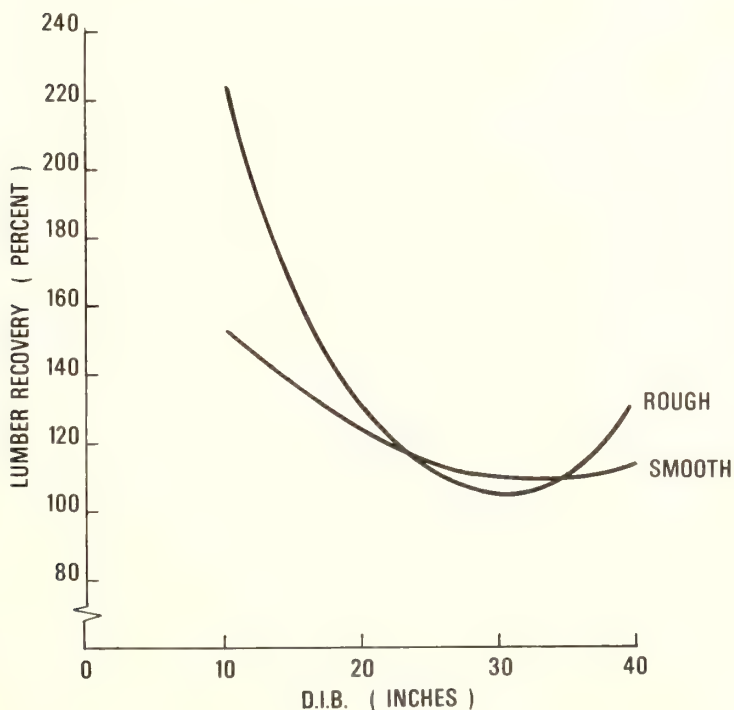


Figure 3.--Recoveries for smooth and rough logs by diameters, in percent of gross log scale. Data from Anderson mill study, 1965.

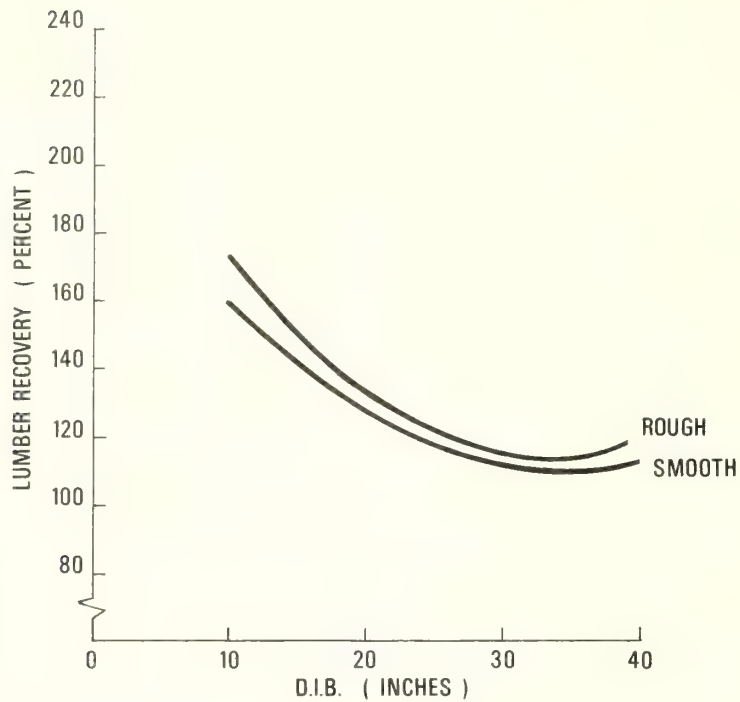
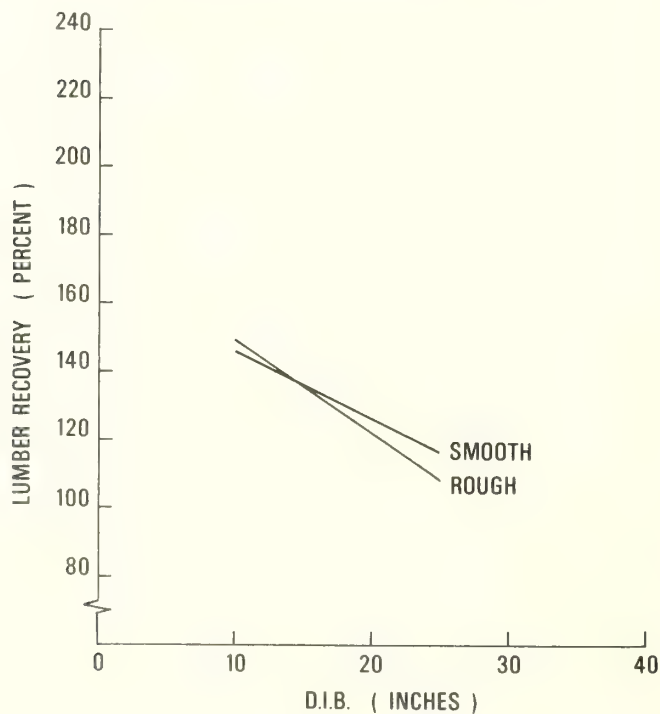


Figure 4.--Recoveries for smooth and rough logs by diameters, in percent of gross log scale. Data from Medford mill study, 1966.



For logs over 20 inches in diameter, however, the smaller difference in average taper, coupled with the presence of large dead knots, was reflected in less lumber recovery for rough logs as compared with smooth logs of like diameters. Table 2 shows average taper of rough and smooth logs for each mill study by 5-inch diameter classes. Table 3 shows average number of live and dead knots over 2 and 3 inches in diameter for rough logs by 5-inch log-diameter classes. A comparison of the information in these tables with the curves shown in figures 1 through 4 will confirm these apparent relationships of taper and knot types to recovery.

The average numbers of live and dead knots over 2 and 3 inches are compared for Mapleton study in table 4. It will be noted that there is considerable contrast in surface appearance between the average smooth and rough log. This relationship is typical for all studies.

Log Value

This investigation is concerned with log roughness as a scaling problem. Although log value as related to roughness is primarily a log grading problem, log value comparisons have been included. This was done only because log value in the form of anticipated lumber grade recovery is presently being considered by many scalers in making deductions from gross scaled log volume where rough logs are concerned.

Comparisons of value in dollars per thousand board feet gross scale are shown graphically in figures 5 through 8. In two cases (Mapleton and Yreka), the curves of value by diameter are significantly different between rough and smooth logs and roughly reflect their corresponding volume recovery curves.^{7/} Higher lumber values were evident for smaller rough logs compared with smooth logs of like diameters; however, larger rough logs again showed less recovery than smooth logs, this time in dollar value terms. The dollar value curves for the Medford and Anderson studies show lower values for rough logs throughout their lengths. The lower mean dollar values for rough logs in these latter two cases are statistically significant.^{8/}

The lower dollar values of rough logs compared with smooth logs over approximately 20 inches in diameter can be reasonably attributed for the most part to the merchantable volume that is apparently lost to large dead knots. It follows, then, that a scale deduction for volume lost to large dead knots will generally compensate for value loss as well. For this reason, no further deduction based on the higher proportion of

^{7/} In both cases, the difference in slopes was significant at the 1-percent level of probability.

^{8/} For these studies, differences in slope were not significant, but means were significant at the 1-percent level.

*Table 2.--Mean taper per 16-foot log, by 5-inch d.i.b. classes,
rough and smooth logs--butt logs excluded*

Mill study	D.i.b. class	Mean taper		
		Rough	Smooth	Difference
----- <u>Inches</u> -----				
Mapleton	6-10	7.0	1.8	5.2
	11-15	3.8	1.4	2.4
	16-20	2.6	1.3	1.3
	21-25	2.9	1.5	1.4
	26-30	2.0	1.8	.2
	31-35	--	1.0	--
Yreka	6-10	5.2	2.7	2.5
	11-15	4.6	2.2	2.4
	16-20	3.9	2.0	1.9
	21-25	3.4	2.1	1.3
	26-30	3.0	1.8	1.2
	31-35	2.4	2.4	0
Anderson	6-10	5.9	3.0	2.9
	11-15	5.0	2.2	2.8
	16-20	4.9	1.8	3.1
	21-25	3.5	1.9	1.6
	26-30	3.3	1.7	1.6
	31-35	2.2	1.9	.3
Medford	6-10	4.8	2.5	2.3
	11-15	4.9	1.8	3.1
	16-20	4.5	1.9	2.6
	21-25	2.4	1.7	.7
	26-30	--	--	--
	31-35	--	--	--

Table 3.--Average number of live and dead knots >2 and >3 inches in diameter
per rough log, by 5-inch log d.i.b. classes

Mill study	D.i.b. class (inches)	Number of knots > 2 inches		Number of knots > 3 inches		Dead knots ^{1/}	
		Live	Dead	Total	Live	Dead	Total
Mapleton	6-10	17.7	10.3	28.0	10.0	4.0	14.0
	11-15	18.2	7.5	25.7	13.5	1.7	15.2
	16-20	7.3	12.1	19.4	5.0	4.9	9.9
	21-25	1.6	26.2	27.8	1.6	17.0	18.6
	26-30	1.3	18.8	20.1	1.3	9.8	11.1
	31-35	--	--	--	--	--	--
Yreka	6-10	30.5	1.0	31.5	27.5	.5	28.0
	11-15	21.6	11.0	32.6	18.3	4.9	23.2
	16-20	18.1	9.8	27.9	17.2	5.3	22.5
	21-25	13.7	10.9	24.6	12.8	6.4	19.2
	26-30	11.2	14.5	25.7	10.6	11.2	21.8
	31-35	6.3	11.3	17.6	6.0	8.3	14.3
Anderson	6-10	22.1	5.7	27.8	19.4	2.0	21.4
	11-15	20.1	9.7	29.8	20.1	6.1	26.2
	16-20	22.1	13.6	35.7	22.1	9.4	31.5
	21-25	14.6	17.1	31.7	14.6	11.3	25.9
	26-30	9.7	15.0	24.7	9.7	10.9	19.6
	31-35	5.8	21.5	27.3	5.8	16.0	21.8
Medford	6-10	28.0	1.0	29.0	23.0	.2	23.2
	11-15	20.0	8.0	28.0	18.5	5.6	24.1
	16-20	15.1	17.0	32.1	13.8	9.8	23.6
	21-25	12.8	16.8	29.6	12.8	10.8	23.6
	26-30	--	--	--	--	--	--
	31-35	--	--	--	--	--	--
				Percent			
						> 2 inches	> 3 inches
						37	29
						29	11
						62	49
						94	91
						94	88
						--	--
						3	2
						34	21
						35	24
						44	33
						56	51
						64	58
						21	9
						33	23
						38	30
						54	44
						61	56
						79	73
						3	1
						29	23
						53	42
						57	46
						--	--
						--	--

^{1/} Number of dead knots expressed as a percentage of total number of knots in each size class.

Table 4.--Average number of live and dead knots >2 and >3 inches in diameter per 16 feet of log length for rough and smooth logs from the Mapleton study

Scaling diameter class (inches)	Rough logs					Smooth logs				
	Live knots		Dead knots		Total > 2	Live knots		Dead knots		Total > 2
	> 2	> 3	> 2	> 3		> 2	> 3	> 2	> 3	
6-10	17.7	10.0	10.3	4.0	28.0	2.4	0.7	1.2	0.4	3.6
11-15	18.2	13.5	7.5	1.7	25.7	2.2	.7	1.5	.1	3.7
16-20	7.3	5.0	12.1	4.9	19.4	1.4	.4	2.2	.4	3.6
21-25	1.6	1.6	26.2	17.0	27.8	.8	.4	3.4	.5	4.2
26-30	1.3	1.3	18.8	9.8	20.2	1.4	.9	4.6	1.4	6.0

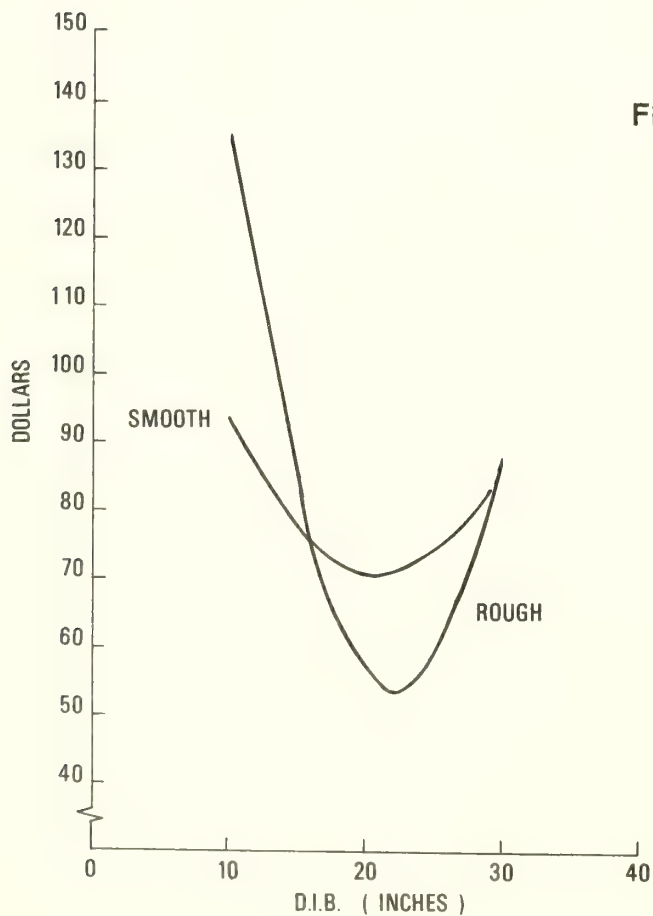


Figure 5.--Values of smooth and rough logs by diameters, in dollars per thousand board feet gross log scale. Data from Mapleton mill study, 1964.

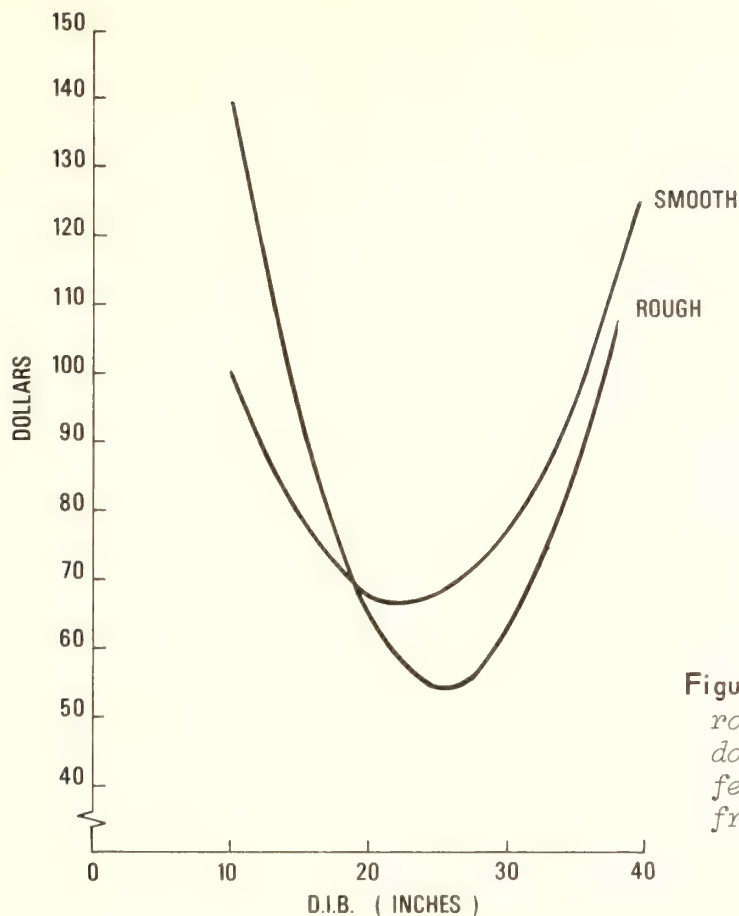


Figure 6.--Values of smooth and rough logs by diameters, in dollars per thousand board feet gross log scale. Data from Yreka mill study, 1965.

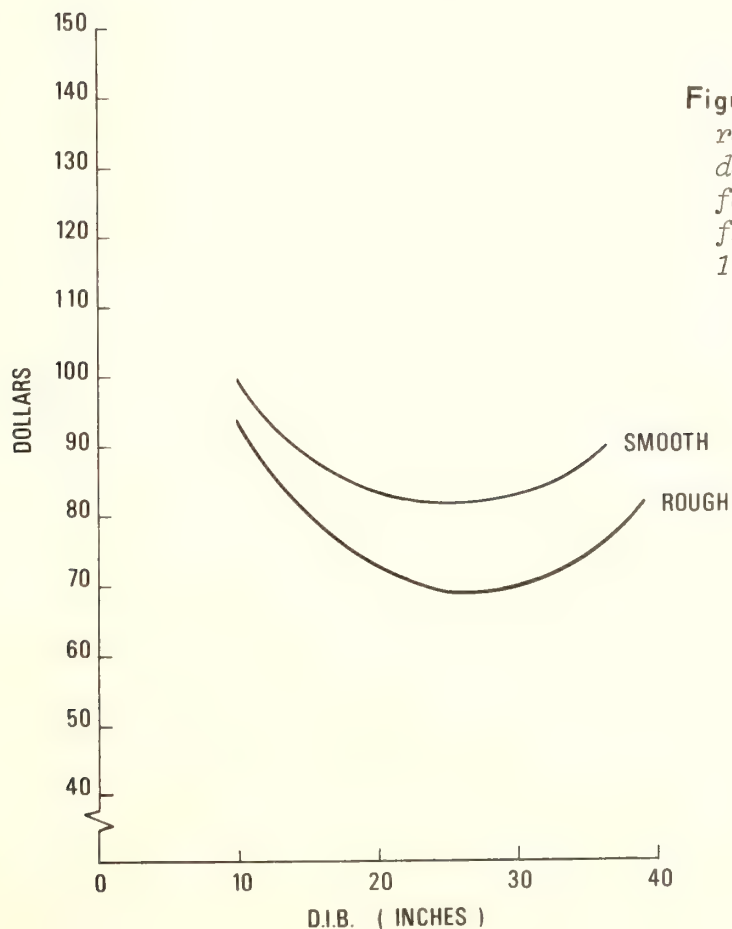


Figure 7.--Values of smooth and rough logs by diameters, in dollars per thousand board feet gross log scale. Data from Anderson mill study, 1965.

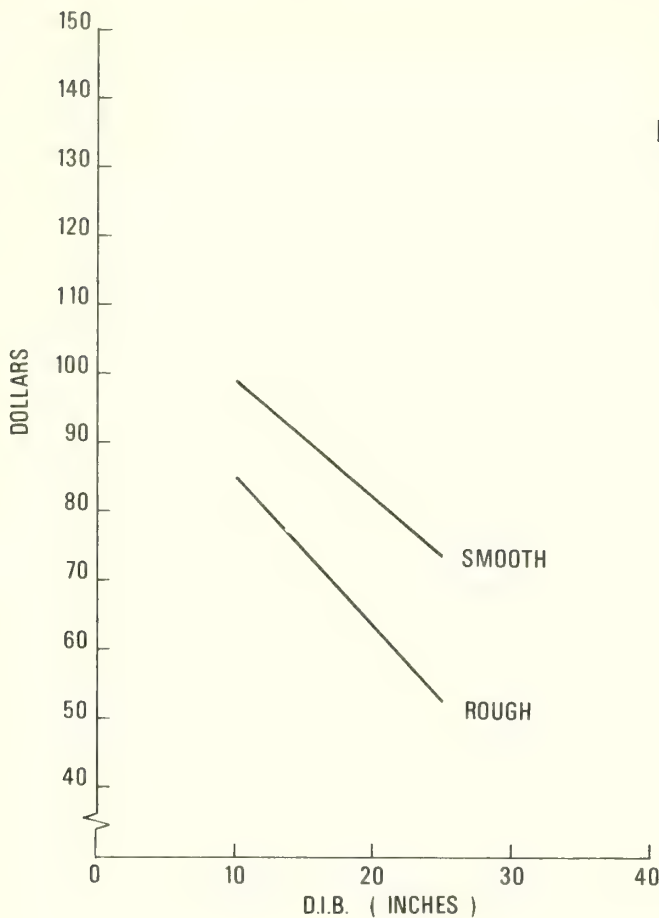


Figure 8.--Values of smooth and rough logs by diameters, in dollars per thousand board feet gross log scale. Data from Medford mill study, 1966.

low-grade lumber in rough logs is justified. Where logs less than 20 inches in diameter were concerned, no firm basis for deductions for roughness existed. The fact that in two cases these rough logs had less average dollar value than smooth logs of the same grade is countered by the fact that in two cases the reverse was also true. Also, as scaling is generally restricted to determining log volume, the problems of assigning value to logs based on end-product yield should be left to log grading. It is likely that a grading system could be developed that would more effectively reconcile log value discrepancies that arise between logs of the same diameter and present grades.

Further Considerations

It was noted that the maximum average difference between volume recoveries, where rough logs showed less recovery than smooth logs in any study, was approximately 15 percent (Mapleton study, figure 1).

This corresponds roughly to a 2-inch deduction where 25-inch logs are concerned. This leads to the recommendation that rough deductions generally should not exceed 2 inches of scaling diameter and that a 1-inch deduction is often more than sufficient, depending on log taper and size of deductible knots.

The determination of what comprises a rough log remains difficult. The samples used in this investigation may provide a rough guide. It appeared that logs showing a sawn volume loss attributable to roughness and warranting a scale deduction had an average of 12 to 15 or more dead knots 2 inches in diameter or larger, of which half or more were 3 inches in diameter or larger, with a rising proportion of knots over 3 inches as log diameters increased. This is hardly the basis for an ironclad rule, as taper and other factors would have to be considered. As a definition, it remains untested, being based only on the data collected for this investigation.

CONCLUSIONS

1. A loss in merchantable log volume may occur when 2-inch and larger dead branch stubs indicate there will be loose knots deeper than 2 or 3 inches from the surface of the log.
2. Large live branch stubs indicate tight knots which have no detectable effect on the merchantable volume that can be recovered in sawing.
3. Log taper is an extremely important consideration where roughness deductions are concerned. Rough logs nearly always have more taper than smooth logs. The effect of taper often compensates for the effect of large loose knots on merchantable log volume.
4. No strict rule regarding the identification of logs warranting a scale deduction for roughness is furnished by this investigation. The data suggest the following as a guide: Logs requiring a roughness deduction are those having 12 or more large (2 or more inches in diameter) dead knots per 16 feet of length, with at least half the total number consisting of 3-inch knots or larger for logs less than 20 inches in diameter or three-quarters of the total consisting of 3-inch knots or larger for logs above 20 inches in diameter.

RECOMMENDATIONS

1. Make volume deduction for log roughness only when dead branch stubs indicate that there will be loose knots deeper than 2 or 3 inches from the surface of the log.
2. Consider taper in every case of apparent roughness to prevent unwarranted deductions for superficial loose knots. Taper not only keeps some superficial dead knots out of cants near the large ends of logs but may also increase the size of the usable cant near the large end.
3. Delete references in present scaling rules to especially knotty top logs as a particular case of roughness requiring a deduction. Such logs generally have the fewest large dead knots and the highest rates of taper. Also, since most top logs have more live limbs than dead, this rule may lead to unwarranted scale deduction if the scaler observes the abundance rather than the soundness of the knots.
4. Scale deductions for large dead knots should not generally exceed the equivalent of 1 or 2 inches of scaling diameter. Limit 2-inch diameter deductions to the more extreme cases of dead knot size and number.

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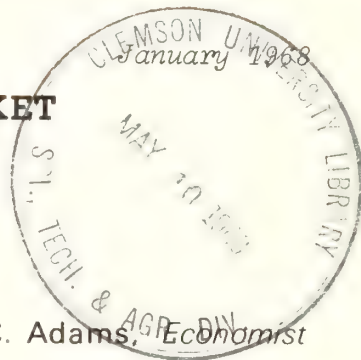
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PNW-74

PRICE TRENDS OF OPEN-MARKET DOUGLAS-FIR LOGS

in western Washington
and northwest Oregon

by Thomas C. Adams, Economist



This report presents information on price trends for the Pacific Northwest region's principal species, Douglas-fir. Forest economists, business managers, and research workers frequently need such information. The following tables were prepared to meet this need. Data are presented by log grade for the years 1936-66 and include a separate series for export logs in the last 4 years.

The information since 1963 is made available by permission of the Industrial Forestry Association, which collected the basic data used in this compilation, as reported in their quarterly "Composite Log Sales Analysis." The data are from log transactions in western Washington and northwest Oregon and for 1966 are estimated to represent 69, 85, and 55 percent of total volume of open-market log transactions in the Puget Sound, Grays Harbor, and Columbia River districts, respectively.¹ This volume is approximately 16 percent of all timber harvested in western Washington and northwest Oregon.

¹ These data bring up to date the price series previously published in "Price Trends and Relationships for Forest Products," House Document No. 195, 85th Congress, First Session, June 13, 1957, U.S. Government Printing Office, Washington, D. C., 58 pp. Open-market log transactions are defined here as sales and purchases of logs between different individuals or independent firms (not between different departments of the same or related firms). The transactions involve logs in rafts in rivers, Puget Sound or other harbors, or at dryland log yards and do not include stumpage sales of standing timber. Northwest Oregon is defined here as approximately from Salem northward.

Log transactions, reported to the Industrial Forestry Association in this series, may take place at a variety of points in the distribution process; e. g., at a river dump, reloading station or truck scaling station, or on delivery to a mill. They provide a simple composite of log prices from a large number of actual transactions, and have long been used to give a general picture of long-term price trends and relationships among the different grades.

Importance of Log Grades

Practically all logs in western Washington and northwest Oregon are sold on the basis of log grade, as defined and determined by the Puget Sound, Grays Harbor, and Columbia River Log Scaling and Grading Bureaus. For Douglas-fir, three peeler grades and three saw-log grades are used. Since 1963, a special fir peeler grade (SFP) and a special mill grade (SM) have been in use. Although the peeler grades were originally intended to help separate veneer logs from logs that would normally be sawn into lumber, this division is now less sharp--many "saw logs" are now being peeled and many "peeler" logs are now being sawn. However, the grade distinctions still serve fairly well to separate logs according to value characteristics, whatever the end use may be.

Wide Variation Among Grades

The average price of No. 3 Douglas-fir saw logs in 1966, for water and inland sales not identified for export, was \$54.90 per thousand board feet, Scribner scale, as compared with \$73.20 for No. 1 grade (fig. 1 and table 1, series A). No. 3 peeler logs averaged \$96.80 per thousand board feet and No. 1 peelers, \$125.70 (table 2). Logs graded SFP or SM averaged \$83.60; these grades are generally similar to the No. 3 peeler grade but permit logs down to 18 or 16 inches in diameter instead of the 24-inch minimum requirement for No. 3 peelers.

Influence of Log Exports

When the Industrial Forestry Association began compiling average log prices from transaction invoices in 1963, it separated transactions into water sales (in market areas on towable waters), export sales (for export outside the United States), and inland sales (in market areas not on towable waters).

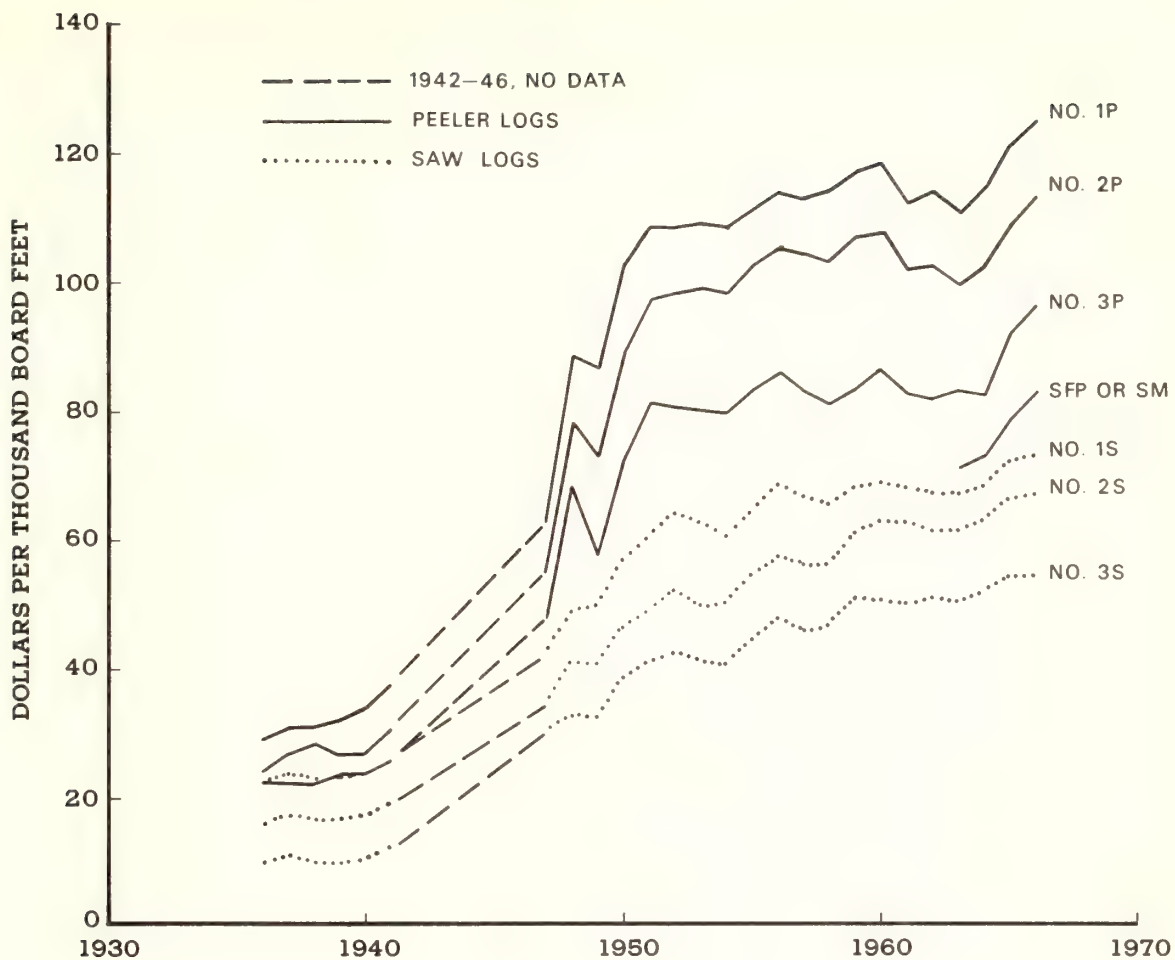


Figure 1.--Average prices for Douglas-fir saw logs and peeler logs, 1936-66 (prices 1963-66 are for water and inland sales, not identified for export).

Table 1.--Douglas-fir saw-log prices, western Washington and northwest Oregon, 1936-66

(Dollars per thousand board feet, Scribner log scale)

Year	Saw logs						
	Grade No. 1, current dollars	Grade No. 2, current dollars	Grade No. 3, current dollars	Mixed grade, current dollars	Ungraded, current dollars	Average ^{2/}	
						Current dollars	1957-59 dollars ^{3/}
1936	22.50	16.00	10.00	--	--	14.00	31.70
1937	24.00	17.50	11.00	--	--	15.50	32.80
1938	23.00	16.50	10.00	--	--	14.50	33.70
1939	23.00	16.50	10.00	--	--	14.50	34.40
1940	24.00	17.50	10.50	--	--	15.50	36.00
1941	26.00	19.00	12.00	--	--	17.00	35.60
1942- 46	--	--	--	--	--	--	--
1947	42.90	34.70	30.40	--	--	33.70	41.50
1948	49.30	41.10	32.80	--	--	39.30	44.70
1949	50.00	40.60	32.60	--	--	39.00	46.70
1950	57.10	46.20	38.70	--	--	44.70	51.50
1951	60.20	49.40	41.70	--	--	47.90	49.50
1952	64.20	52.40	42.90	--	--	50.60	53.80
1953	62.30	49.70	41.10	--	--	48.00	51.80
1954	60.40	50.20	40.70	--	--	48.10	51.80
1955	64.50	54.60	44.80	--	--	52.20	56.00
1956	68.60	57.90	48.00	--	--	55.10	57.30
1957	66.20	56.00	46.00	--	--	52.80	53.30
1958	65.90	56.50	47.00	--	--	53.10	52.90
1959	68.30	61.50	51.20	--	--	57.70	57.40
1960	68.90	63.00	50.70	--	--	58.40	58.00
1961	68.10	63.00	50.20	--	--	57.50	57.30
1962	67.10	61.90	51.20	--	--	57.40	57.10
Series A (water and inland sales, not identified for export):							
1963 ^{4/}	67.30	61.90	50.60	--	51.20	57.90	57.70
1964	68.30	63.50	52.10	60.40	38.30	57.70	57.40
1965	72.10	66.60	54.20	66.60	44.20	61.50	60.00
1966	73.20	67.60	54.90	71.00	49.20	62.30	58.80
Series B (sales for export outside the United States):							
1963 ^{4/}	--	69.70	58.20	--	54.30	61.60	61.40
1964	90.00	71.70	60.10	78.80	58.40	68.50	68.20
1965	69.60	78.70	60.70	81.40	51.10	72.50	70.70
1966	72.00	80.50	63.90	78.20	78.30	77.10	72.80
Series C (all sales reported):							
1963 ^{4/}	67.30	62.70	52.70	--	52.00	58.50	58.30
1964	68.40	64.90	53.40	64.60	39.50	59.50	59.20
1965	71.80	67.90	55.40	69.70	44.20	63.00	61.50
1966	73.20	70.00	56.10	74.70	50.50	65.00	61.90

^{1/} Excludes cull logs and wood logs. Compilation excludes camp run logs occasionally reported 1936-61.

^{2/} New average series begins 1963, due to inclusion of additional grade classifications and separation into series A (water and inland sales, not identified for export), series B (sales for export outside the United States), and series C (all sales reported).

^{3/} Adjusted by wholesale price index for all commodities as reported by the Bureau of Labor Statistics.

^{4/} Data for 1963 include third and fourth quarters only.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Pacific Northwest Loggers Association (1936-62) and Industrial Forestry Association (1963-66). These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction.

Table 2.--Douglas-fir peeler log prices, western Washington and northwest Oregon, 1936-66

(Dollars per thousand board feet, Scribner log scale)

Year	Peeler logs					
	Grade No. 1, current dollars	Grade No. 2, current dollars	Grade No. 3, current dollars	SFP or SML ^{1/}	Average ^{2/}	
					Current dollars	1957-59 ^{3/} dollars
1936	29.00	24.00	22.50	--	25.00	56.60
1937	31.00	26.50	22.50	--	27.50	58.30
1938	31.00	28.00	25.50	--	29.00	67.40
1939	32.00	26.50	23.50	--	27.50	65.20
1940	34.00	27.00	24.00	--	28.00	65.10
1941	38.00	31.00	26.00	--	32.00	67.00
1942- 46	--	--	--	--	--	--
1947	62.90	55.40	48.10	--	56.40	69.50
1948	88.90	78.10	68.90	--	79.70	90.70
1949	86.90	72.90	57.00	--	74.90	89.70
1950	102.60	89.00	73.60	--	89.40	103.00
1951	108.20	97.30	81.80	--	96.50	99.80
1952	108.40	98.20	80.70	--	96.00	102.10
1953	109.60	98.80	80.20	--	96.30	103.90
1954	109.00	98.40	79.60	--	94.80	102.00
1955	111.50	102.30	83.40	--	96.30	103.30
1956	114.20	105.50	86.20	--	99.10	103.00
1957	113.40	104.20	83.20	--	98.70	99.70
1958	114.60	103.70	81.00	--	95.70	95.30
1959	117.90	107.30	83.90	--	97.10	96.50
1960	118.70	108.00	86.80	--	100.10	99.40
1961	112.30	102.20	83.00	--	94.90	94.62
1962	114.30	103.30	82.20	--	95.00	94.40
Series A (water and inland sales, not identified for export):						
1963 ^{4/}	111.30	99.90	83.90	71.20	86.00	85.70
1964	114.80	102.20	82.30	73.40	85.80	85.40
1965	121.80	109.40	92.50	78.50	93.90	91.60
1966	125.70	114.00	96.80	83.60	97.90	92.40
Series B (sales for export outside the United States):						
1963 ^{4/}	135.00	135.00	88.80	75.00	76.00	75.80
1964	123.90	112.50	97.40	82.20	86.20	85.80
1965	140.30	117.50	100.70	89.10	93.90	91.60
1966	142.00	128.30	103.40	89.90	96.40	91.00
Series C (all sales reported):						
1963 ^{4/}	111.40	100.00	84.00	72.00	85.20	84.40
1964	114.80	102.30	83.10	74.50	85.80	85.40
1965	122.40	109.50	92.80	80.30	93.90	91.60
1966	127.60	114.90	97.70	86.10	97.50	92.10

^{1/} Special fir peeler or special mill grade.

^{2/} New average series begins 1963 due to inclusion of additional grade classifications and separation into series A (water and inland sales, not identified for export), series B (sales for export outside the United States), and series C (all sales reported).

^{3/} Adjusted by wholesale price index for all commodities as reported by the Bureau of Labor Statistics.

^{4/} Data for 1963 include third and fourth quarters only.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Pacific Northwest Loggers Association (1936-62) and Industrial Forestry Association (1963-66). These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction.

The export log prices tend to be noticeably higher than other log prices for three reasons:

1. Export log specifications on individual orders typically allow fewer large knots and require logs to be mostly free of rot or other defects; as a consequence, export logs tend to be the "top of the grade."
2. Some of the export log transactions may take place alongside ships ready for loading and would therefore reflect extra cost of towing, storage, sorting, scaling, rebucking, and other handling.²
3. It may be reasoned that, as increasing levels of export orders are filled, it becomes necessary for the export dealers to bid these logs away from other established channels.

Adjusted Log Prices

The average saw-log and peeler-log prices of tables 1 and 2 show prices in both current dollars and in 1957-59 dollars. The latter is an adjustment for changes in the national price level calculated by dividing the log price in current dollars by the U.S. Bureau of Labor Statistics wholesale price index for all commodities.

Trend of Log Prices

Prices of all grades increased sharply between 1940 and 1951, but from about 1952 to the present have shown a more moderate trend of increase, with some temporary declines in the period 1961-64. For example, Douglas-fir saw logs were selling for an average of \$15.50 per thousand board feet in 1940, \$33.70 in 1947, \$47.90 in 1951, and \$62.30 in 1966, in current dollars. The changes in constant 1957-59 dollars were less pronounced.

² The "export sales" classification includes all reported transactions identified for export, whether at initial water or inland scaling points, intermediate points, or delivered alongside ship.

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PNW-75

February 1968

SMALL MAMMALS AND NATURAL REFORESTATION IN SOUTHEAST ALASKA

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Institute of Northern Forestry

ABSTRACT

Biannual (May or June and September), small-mammal censuses were made for 9 years on a cutover and a timbered plot in Maybeso Creek valley near Hollis, Prince of Wales Island, Alaska. *Peromyscus*, *Microtus*, and *Sorex* were captured on both plots. Over the study period, *Peromyscus* were six times more plentiful in the timber, whereas *Microtus* were six times and *Sorex* twice as numerous on the cutting. The greatest number of animals were caught in the spring of 1958, the fewest in the spring of 1963. Adequate natural regeneration of approximately 550 Sitka spruce and western hemlock seedlings per acre became established on the cutover plot despite the presence of small mammals.

INTRODUCTION

When large-scale pulpwood logging began in southeast Alaska in 1953, small mammals were considered a hazard to natural conifer regeneration. Adequate natural reforestation is sometimes difficult to obtain on valley-bottom sites, and the presence of these animals, whose diet includes tree seeds and seedlings, was expected to aggravate the problem.

Small-mammal studies were started on the Maybeso Experimental Forest near Hollis, Prince of Wales Island, in 1954 (James 1956)¹ and expanded in 1956. Four species of small mammals were

¹ Names and dates in parentheses refer to Literature Cited, p. 7.

found living in the area (McGregor 1958): the deer mouse (Peromyscus maniculatus hylaeus (Osgood)), dusky shrew (Sorex obscurus longicauda (Merriam)), long-tailed vole (Microtus longicaudus littoralis (Swarth)), and northern flying squirrel (Glaucomys sabrinus zapheus (Osgood)). Beginning in 1957, an annual spring and fall census was made within a 700-acre clearcut and in an adjacent mature old-growth timber stand. Censuses continued through the regeneration period until 1965, when the study was terminated. This report describes fluctuations in small-mammal population during the regeneration period and the status of natural reforestation on the cutover study area 11 years after logging.

METHODS

In May 1957, two 1-acre trapping plots were located a half mile apart on nearly flat alluvial land in the Maybeso Creek valley. One plot was within a large cutting logged in 1955 (fig. 1), approximately 2,000 feet from the nearest seed source. The second was about 300



Figure 1.--Cutover trapping site 11 years after logging (1965).

feet from the edge of the clearcut beneath an overmature old-growth Sitka spruce (Picea sitchensis (Bong.) Carr.) and western hemlock (Tsuga heterophylla (Raf.) Sarg.) stand similar to the stand harvested on the cutover trapping site (fig. 2). The old-growth stand was somewhat open with a brushy understory of salmonberry (Rubus spectabilis),



Figure 2.--Timbered trapping site (1965).
The area supports an old-growth western
hemlock--Sitka spruce stand.

Pacific red elder (Sambucus callicarpa), and devilsclub (Oplopanax horridus). The timbered site contained 52 trees per acre ranging from 12 to 72 inches in diameter, with dominant spruce 200 feet tall. Gross stand volume was 156,000 board feet (Scribner) per acre.

Each trapping plot was gridded with 100 stakes arranged in 10 lines of 10 stakes each, at intervals of 20.8 feet. Outermost stakes were 10.8 feet inside the plot boundary. Each May or June and September during the study period, one snaptrap was set near a runway or under slash or a log near each stake. Ordinary household mousetraps were used, baited with a mixture of peanut butter and oatmeal.

Trapping was done for three consecutive nights, with traps set and examined daily. The genus, age, and sex of each trapped animal were recorded by date and location.

Stocking percent, number of seedlings per acre, and vegetative cover on the cutover plot were determined at the end of the 1966 growing season from examination of one hundred 4-milacre quadrats centered about stakes marking trap locations.

RESULTS

During the study period, twice as many animals were captured on the timbered area as on the clearcut area, an average of 32 animals per trapping period in the timber and 16 on the cutting. Peromyscus were the most numerous in the timbered habitat, but Microtus and Sorex preferred the more open conditions on the cutting. Peromyscus were six times more plentiful in the timber, whereas Microtus were six times and Sorex over twice as numerous on the cutting. Although flying squirrels were known to live in the area, none were caught, probably because the traps used were too small.

Population peaks differed by species and habitat, but the high population levels which occurred during 1958 were not repeated during the study period. The greatest number of animals were caught in the spring of 1958, the fewest in the spring of 1963 (fig. 3).

Next to small mammals, large slugs, tentatively identified as Ariolimax columbianus (Gould), were the most numerous animals captured. Slugs were adept at removing bait without springing traps, as shown by the slime trail on many robbed traps, and when caught they deposited a sticky mass of slime on the trap. Thus, slugs spoiled many traps for exposure to small mammals.

A heavy crop of both hemlock and spruce cones occurred in 1959, with seedfall beginning in October and extending into the following spring. However, small-mammal populations appeared to be little affected in 1960. Apparently, neither the abundant seed nor unusually heavy seedling germination had a pronounced effect on population numbers.

By the end of the study period, the cutover plot was adequately stocked with spruce and hemlock seedlings. Fifty percent of 4-milacre plots were stocked with at least one well-established seedling at least 6 inches tall, and conifer reproduction occupied 7 percent of the ground cover. Average height of the largest spruce on each quadrat was 8 feet; hemlock, 13 feet. Approximately 440 spruce and 110 hemlock seedlings per acre were established. Most dominant seedlings were established during the first 2 years after logging or were advanced seedlings already established before logging. No seedlings were established after 1960. Dense brush became established soon after logging. In 1966, salmonberry, lady fern (Athyrium filixfemina (L.) Roth.), and various grasses and sedges were the most common species, occupying 39, 26, and 16 percent of ground cover, respectively. Vegetation on the study plot appeared to be representative of the surrounding area.

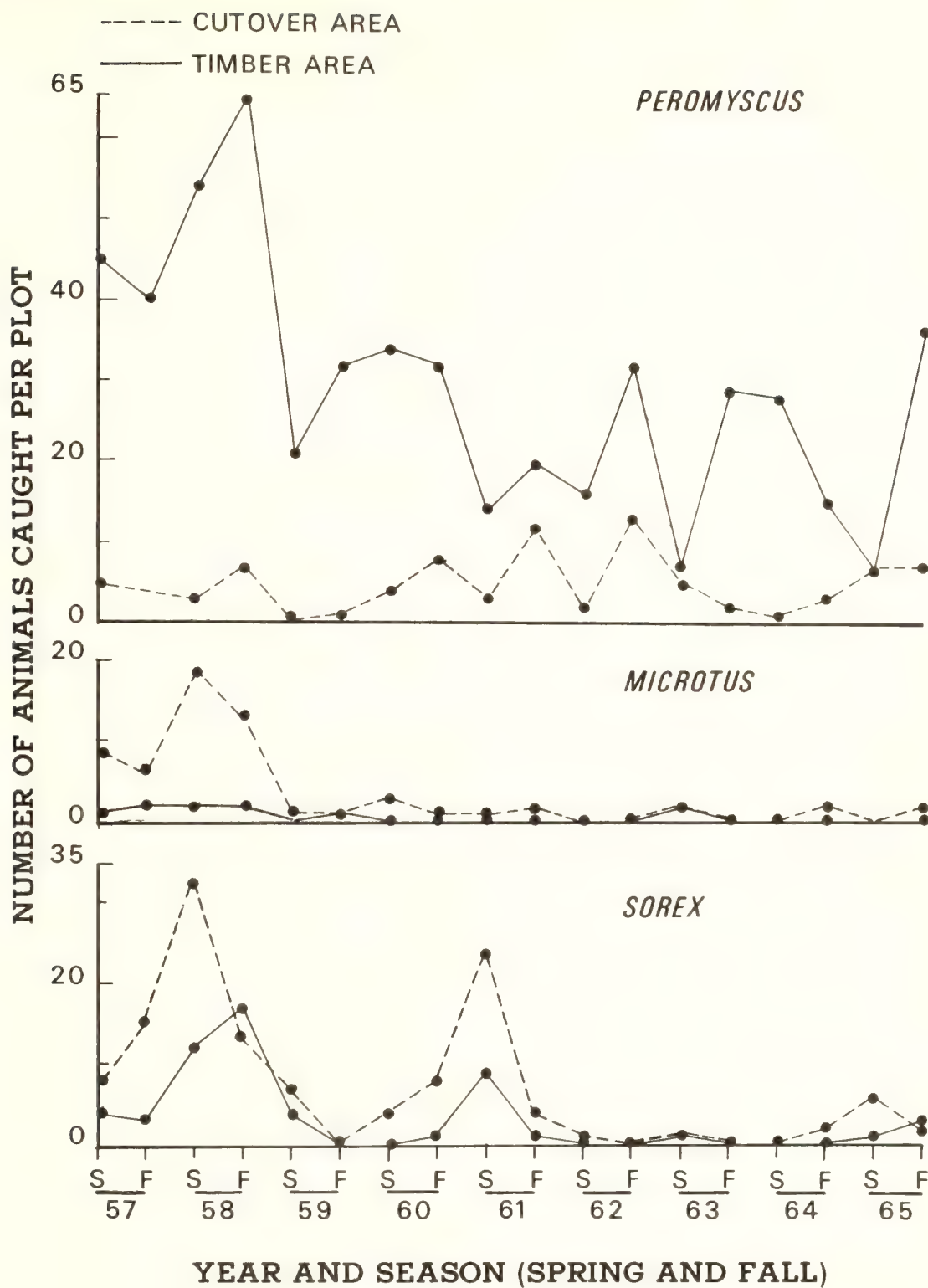


Figure 3.--Number of small mammals caught during 3 nights on which traps were set on cutover and timberland, 1957-65. Maybeso Experimental Forest.

DISCUSSION

The theory underlying population estimates by the removal method is that, if an area is saturated with traps for a period of several nights, the entire resident population or a substantial fraction thereof may be removed.

As pointed out by Zippin (1958) one would expect the greatest number of individuals to be caught and removed the first night, with fewer individuals caught each succeeding night until the population became depleted. In the study reported here, this pattern was apparent in less than 15 percent of the trapping periods, and in 20 percent of the periods, more individuals were trapped on the last night than on the first. Most of the time, no particular pattern was evident. Although weather, especially rain, may have been a factor in animal activity, no correlation with number of captures was apparent. When all trapping periods were averaged, the percentage of animals trapped during three successive nights was: Peromyscus, 39, 33, and 28; Microtus, 44, 28, and 28; Sorex, 34, 30, and 36. Thus, a composite view of captures would seem to indicate that three trapping nights were insufficient to capture all resident animals, or that nonresidents moved into the trapping areas. Therefore, the numbers shown in figure 3 probably do not indicate the total population. However, they are useful as an index of relative abundance over the study period. The cumulative effect of biannual trapping on population numbers is not known.

It has been reported that Peromyscus populations and most Microtus and Sorex populations increase after logging, although exceptions occur. For example, in the California Douglas-fir region, Tevis (1956) found that logging caused an increase in the numbers of Peromyscus and a decrease in the numbers of Sorex. In the case of Peromyscus, the differences were most marked on a 6-year-old cutting, least on a 20-year-old cutting. Thus, in the study reported here, the finding that, at least after the 2d year following logging, fewer Peromyscus were caught on the cutting than in timber was unexpected. The reason is not known.

A small-mammal census was not made during the 1st year after clearcutting, and annual records of seed or seedling losses were not obtained. As a consequence, it is impossible to determine the extent of damage caused or what stocking percent and number of seedlings per acre would have been established had small mammals been absent. However, it is evident that adequate natural regeneration has become established 2,000 feet from the nearest seed source despite the presence of a resident small-mammal population.

Many studies have shown that caged small mammals will consume large quantities of tree seed, and damage to seed and seedlings in the field has been noted (Radwan 1963). Thus, in some cases, small mammals may be a serious threat to regeneration.

At one time, small mammals were thought to be only detrimental to the forest because of their known habits of eating tree seed and seedlings. However, small mammals also have a useful place in forest ecology (Hamilton and Cook 1940; Hamilton 1941). Their insectivorous nature, large numbers, and year-round activity may make them more useful than birds in controlling some insect pests. They are active on the forest floor in working the soil and duff layers, allowing better penetration of air and water. They also serve as food for important fur bearers and act as buffer species, lessening predation on some species of small game. In view of their useful role in forest ecology, it is encouraging to find that small mammals may not be an obstacle to natural conifer regeneration in southeast Alaska.

LITERATURE CITED

Hamilton, W. J.

1941. The food of small forest mammals in eastern United States. J. Mammal. 22: 250-263.

_____ and Cook, D. B.

1940. Small mammals and the forest. J. Forest. 38: 468-473.

James, G. A.

1956. The rodent problem on cutover areas in southeast Alaska. U.S. Forest Serv., Alaska Forest Res. Center Tech. Note 31, 2 pp.

McGregor, R. C.

1958. Small mammal studies on a southeast Alaska cutover area. U.S. Forest Serv., Alaska Forest Res. Center Sta. Pap. 8, 9 pp., illus.

Radwan, M. A.

1963. Protecting forest trees and their seed from small mammals. (A review of the literature.) U.S. Forest Serv. Res. Pap. PNW-6, 28 pp.

Tevis, Lloyd, Jr.

1956. Responses of small-mammal populations to logging of Douglas-fir. J. Mammal. 37: 189-196.

Zippin, C.

1958. The removal method of population estimation. J. Wildlife Manage. 22: 82-90.

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Research Note

FOREST AND RANGE EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE • PORTLAND, OREGON

PNW-76

April 1968

IMPORTANCE OF TIMBER-BASED EMPLOYMENT TO THE ECONOMIC BASE OF THE DOUGLAS-FIR REGION OF OREGON, WASHINGTON, AND NORTHERN CALIFORNIA

by

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ABSTRACT

Degree of economic dependency upon timber industries was estimated for 15 subareas of the Douglas-fir region of Washington, Oregon, and California. This analysis was part of a study of how the region's forest resources can better contribute to the economic growth and development of the Douglas-fir region. Dependency, measured in terms of the percent of economic (or export) base employment accounted for by timber-dependent industries, ranged from 6.2 percent for the Seattle economic area to 99.4 percent for the Roseburg area. Timber-dependent industries accounted for approximately 45 percent of the Douglas-fir region's economic base employment.

The Pacific Northwest Forest and Range Experiment Station is studying how forest resources can better contribute to economic growth of the Douglas-fir region. One of the first tasks of this study was to estimate the dependency of the region's economy upon timber-based industries (i.e., "Lumber and Wood Products," SIC 24; "Paper and Allied



Products," SIC 26; and, "Forestry," SIC 08).^{1/} The purpose of this note is to show (1) how the degree of dependency was estimated and (2) how dependency varies between subareas of the region.

Analysis Utilizes Economic Base Concept

The criterion for this analysis of timber dependency is the economic base concept. The economic base as used here is the employment within a community or region that produces goods and services for markets outside the community or region. In contrast, service or residentiary employment produces for local consumption. Generally speaking, most manufacturing employment is classified as economic base, while service employment (e.g., barber shops, realty firms, schools, and local government) is primarily geared to local needs.

Residentiary employment is supported by a community's (or region's) economic base. Dollar inflows from export sales of the products of the economic base industries provide income to wage earners and entrepreneurs to spend on locally purchased goods and services. In most cases, the economic growth of a community or region is dependent upon the success of its economic base. As Andrews points out, "If a community's trade balance becomes negative for a considerable period or if the exporting functions decline in activity...an eventual downward adjustment in total community population is almost certain to result."^{2/}

Excess-Employment Techniques Used to Estimate Economic Base

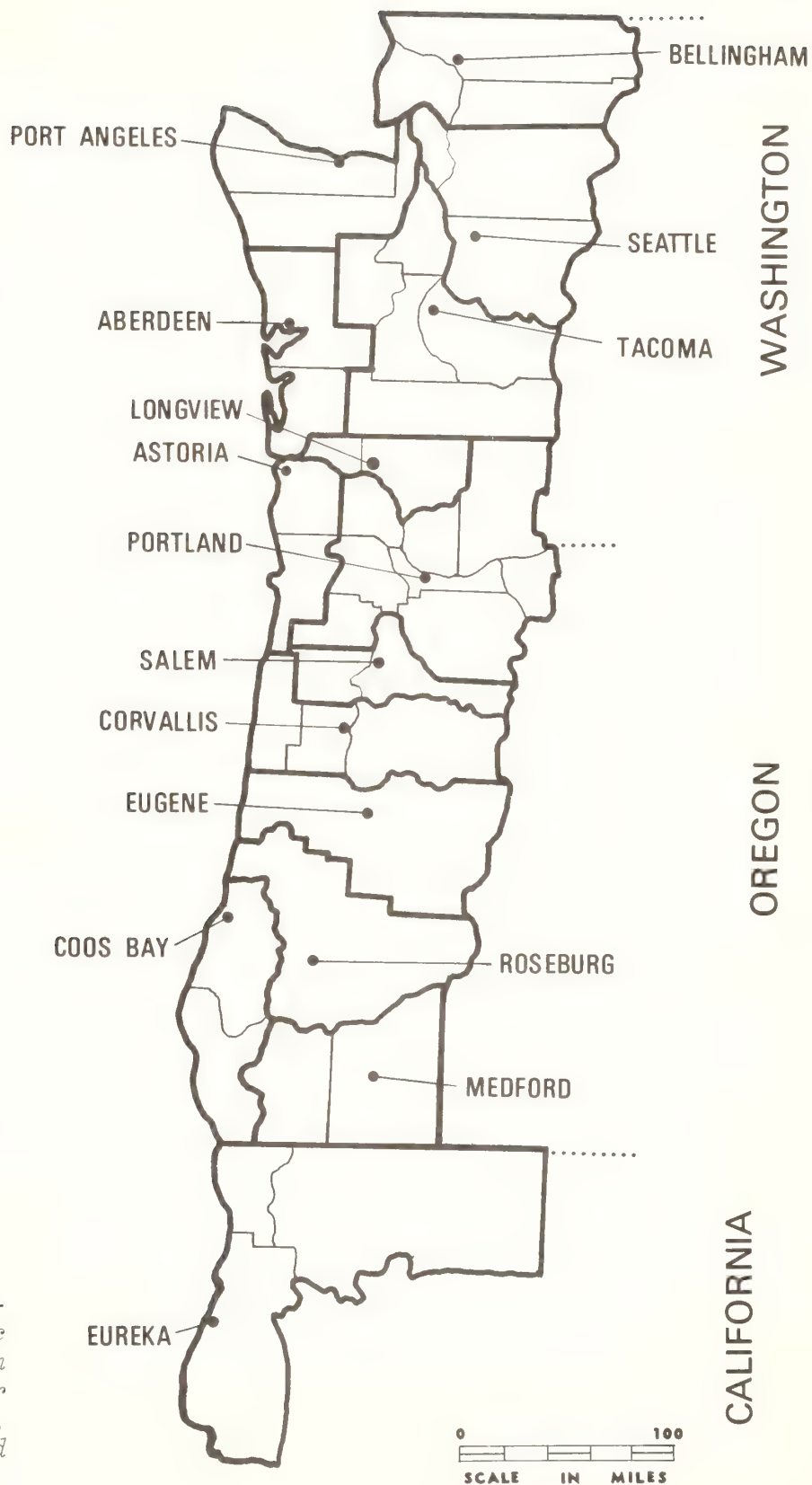
In order to assess variation in timber dependency, we divided the 41-county Douglas-fir region into 15 economic areas, based essentially on commuting distances and shopping patterns (fig. 1). The largest city in each economic area is identified as the growth center, since typically it is the most rapidly growing part of an economic area. The growth center and its surrounding communities represent an economic area characterized by a high degree of interdependence and internal economic linkages.

We used the excess-employment technique to identify the portion of the employment in each area which was engaged in economic base

^{1/} Standard Industrial Classification (SIC) from Bureau of the Budget, "Standard Industrial Classification Manual, 1967."

^{2/} Andrews, Richard B. Mechanics of the urban economic base: historical development of the base concept. Land Econ. 29(2): 161-167.

Figure 1.--
Economic
areas and growth
centers in Douglas-fir
region of Oregon,
Washington, and
northern California.



activities.^{3/} This approach, in its simplest form, accepts the national distribution of employment among industries as a norm. For any sector of an area's economy, an industry with employment in excess of this norm is considered to be producing for export markets, and therefore is part of the area's economic base. For example, in the Eugene economic area, i.e., Lane County, only one manufacturing industry group--lumber, wood products and furniture--is shown as having had excess employment in 1960 (table 1). Two "other commodity" producing industry groups--forestry and fisheries and contract construction--also were shown to be export producing. In addition, because of the services provided by businesses in the Eugene economic area to residents of other economic areas, six "noncommodity" or service industry groups are also considered as being export producing and thus are part of the Eugene area economic base. Altogether, 29.5 percent of the total employment in the Eugene economic area was in excess of the national norm and was therefore defined as being engaged in export production.

Used as indicators of area employment in timber-dependent manufacturing and forestry activities were the percentage of an area's excess employment in three industry groups: lumber, wood products, and furniture; other and miscellaneous manufacturing; and forestry and fisheries.^{4/} In the Eugene economic area, for example, excess employment in timber-dependent industries was 22.6 percent of total employment, or 13,000 workers in 1960. An additional 3,900 workers were considered excess employment in contract construction and noncommodity producing activities. Thus, 76.6 percent of the total 1960 excess employment in the Eugene economic area was in timber-dependent manufacturing and forestry activities. This percentage is defined as the timber-dependency indicator.

^{3/} This technique was used in the early 1940's in studies of the U.S. economy (Hoover, Edgar M. Jr. Industrial location and national resources. Nat. Resources Planning Board. 1943). Refinements in the technique were made recently for comparative community studies (Ullman, Edward L., and Dacey, M. F. The minimum requirements approach to the urban economic base. Pap. Proc. Reg. Sci. Ass. 6: 175-194. 1960). Our use of the excess-employment technique yields results which are not significantly different from the more refined approaches.

^{4/} These three industry groups are the ones containing "Lumber and Wood Products," SIC 24, "Paper and Allied Products," SIC 26, and "Forestry," SIC 08. There may be some distortion in using the industry group as if it represented the specific industry because there are other industries included in each group. However, this distortion is considered minimal because industry classes SIC 24, SIC 26, and SIC 08 heavily dominate their respective industry groups in the Douglas-fir region.

Table 1.--Percentage of total and excess employment in specified industrygroups in the Eugene economic area and the United States, 1960

(In percent)

Industry group	Eugene economic area	United States	Excess employment in the Eugene economic area ^{1/}
Manufacturing:			
Food and kindred products	2.2	2.9	--
Textile mill products	(^{2/})	1.5	--
Apparel	(^{2/})	1.9	--
Lumber, wood products, furniture	23.8	1.7	22.1
Printing and publishing	1.4	1.8	--
Chemicals and allied products	0.1	1.4	--
Electrical and other machinery	0.9	4.9	--
Motor vehicles and equipment	(^{2/})	1.4	--
Other transportation equipment	0.1	1.6	--
Other and miscellaneous	1.1	9.1	--
Total manufacturing ^{3/}	29.8	28.3	22.1
Other commodity:			
Agriculture	3.7	6.9	--
Forestry and fisheries	0.6	0.2	0.5
Mining	0.3	1.1	--
Contract construction	7.0	6.2	0.8
Total other commodity ^{3/}	11.6	14.2	1.3
Noncommodity:			
Railroads and railroad express	3.1	1.5	1.5
Trucking and warehousing	1.3	1.5	--
Other transportation	0.6	1.4	--
Communications	1.3	1.3	--
Utilities and sanitary services	1.4	1.4	--
Wholesale trade	4.1	3.6	0.4
Food and dairy products stores	2.5	2.7	--
Eating and drinking places	3.1	2.9	0.2
Other retail trade	10.2	9.8	0.4
Finances, insurance, and real estate	3.0	4.3	--
Hotels and other personal services	3.4	3.1	0.2
Private households	2.9	3.1	--
Business and repair services	2.6	2.6	--
Entertainment and recreation services	0.6	0.8	--
Medical and professional services	15.5	12.2	3.2
Public administration	3.2	5.2	--
Total noncommodity ^{3/}	58.6	57.5	6.1
Total employment ^{3/}	100.0	100.0	29.5

^{1/} Dash signifies no excess employment. Figures may not be exactly equal to Eugene minus U.S. due to rounding.

^{2/} 0.05 percent or less.

^{3/} Sum of parts may not equal totals due to rounding.

Timber Dependency Varies Between
Economic Areas of Douglas-Fir Region

Highly timber-dependent areas were defined as those with a timber-dependency indicator of 70 percent or greater, whereas moderately timber-dependent areas can be identified by timber-dependency indicator of 30 to 69 percent (see table 2). Only three economic areas--Seattle, Portland, Salem--were slightly timber dependent (less than 30 percent), but nine areas were highly timber dependent.

Table 2.--Classification of economic areas by degree
of dependency upon timber-based employment

Dependency	Economic area ^{1/}	Percentage of 1960 excess employment dependent on timber-based employment
Slight	Seattle	6.2
	Portland	23.8
	Salem	29.3
Moderate	Bellingham	30.4
	Tacoma	32.5
	Astoria	63.1
High	Medford	70.0
	Corvallis	74.3
	Eugene	76.6
	Longview	81.5
	Aberdeen	88.1
	Eureka	89.6
	Port Angeles	90.5
	Coos Bay	91.6
	Roseburg	99.4
Douglas-fir region		44.8

^{1/} Economic areas are identified by the names of their respective growth centers.

Research Note

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PNW-77

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RESPONSE OF PONDEROSA PINE POLE STANDS TO THINNING

by

James W. Barrett, *Silviculturist*ABSTRACT

Thinning dense ponderosa pine pole stands on site V in northern Washington will promote greater diameter growth per tree and greater wood production on trees that will reach usable size. Trees spaced 13.2, 18.7, and 26.4 feet apart grew in diameter at the rate of 2.0, 2.6, and 3.2 inches per decade, respectively. Comparable trees in the unthinned plots grew only 0.63, 0.68, and 0.73 inches per decade. Height increment did not differ between spacings for trees of comparable initial diameters. The closest spacing produced about 31 cubic feet per acre per year compared to 19 cubic feet at the widest spacing.

Stand density control is the forester's principal tool for speeding up growth of individual trees and concentrating wood production on those trees that will reach usable size. Thinning to provide desirable tree spacing is especially important in dense stands of sapling and small pole-sized ponderosa pine (*Pinus ponderosa*) growing on poor sites. Growth of individual trees is usually extremely slow in such stands, and wood production is diffused among a large number of stems most of which will never reach usable size.

Definition of the optimum tree spacing required to fit a given market and site condition remains elusive. This note reports first 5-year results of one of a series of spacing studies designed to help foresters choose the initial spacing that will best fit their site and anticipated market conditions.^{1 2}

¹ Barrett, James W. Spacing and understory vegetation affect growth of ponderosa pine saplings. Pacific Northwest Forest & Range Exp. Sta. U.S. Forest Serv. Res. Note PNW-27, 8 pp., illus. 1965.

² Barrett, James W. Dominant ponderosa pines *do* respond to thinning. Pacific Northwest Forest & Range Exp. Sta. U.S. Forest Serv. Res. Note PNW-9, 8 pp., illus. 1963.



THE STUDY AREA

A healthy stand of 47-year-old ponderosa pine saplings and poles on site V land³ was selected for the study (figs. 1, 2, and 3).

The study is located in north-central Washington, near the town of Winthrop. The stand is about 600 feet above the Methow River at an elevation of 2,350 feet. Precipitation averages 14.5 inches annually. The soil is a well-drained Katar sandy loam.



Figure 1.--Control plot containing
129 square feet of basal area.

³ Meyer, Walter H. Yield of even-aged stands of ponderosa pine. U.S. Dep. Agr. Tech. Bull. 630 (rev.), 59 pp., illus. 1961.

Figure 2.--Stand thinned
to 250 trees per acre.



Figure 3.--Stand thinned
to 125 trees per acre.



The land, owned and administered by the Washington State Department of Game, is known as the Methow Game Range. Before study installation, inspection of previously thinned stands on the game range indicated some accelerated tree growth plus improvement in forage. However, the best spacing for maximizing wood and forage production was not apparent from these original thinnings. Therefore, a combination spacing, wood increment, and forage production study was initiated.

EXPERIMENTAL DESIGN AND METHODS

The experiment consists of thinning to average spacings of 13.2 feet (250 trees per acre), 18.7 feet (125 trees per acre), and 26.4 feet (62 trees per acre), and no thinning. Each treatment is replicated three times in a randomized block design, thus making a total of 12 rectangular 1/5-acre plots. Uniform spacing was sought in marking leave trees, but it was not always possible to find the best tree at the right point. However, the best tree was chosen within a radius of one-third the spacing distance from the point of ideal spacing.

All trees on the thinned plots were measured to the nearest 0.1 inch in diameter, breast high, and to the nearest 0.1 foot in height. Sample trees on each plot were climbed and diameter and bark thickness measured at 5-foot intervals up the tree. These sample trees formed the basis for calculating formulas that express volume of the entire stem as a function of diameter and height. Formulas were then used to calculate plot volumes.

Trees on control plots were tallied by diameter classes at the beginning of the period, and therefore, values shown in table 1 for age 47 are approximate. As a result, an accurate volume could not be calculated for this age, and no volume increments are reported for control plots. At age 52, all trees on control plots were measured to the nearest 0.1 inch, thus providing a base for accurate volume and volume increment estimates in the future. In addition, a sample of trees in the 52-year-old stand were climbed, measured, and volumes expressed as a function of diameter in formula form.

Thinning was done in the fall, early winter, and spring at age 47. Slash was removed from the plots and burned outside the perimeter of the plot.

⁴ A cooperative study between the Washington State Department of Game and U.S. Department of Agriculture, including the Soil Conservation Service, Okanogan National Forest, and the Pacific Northwest Forest and Range Experiment Station.

RESULTS

Diameter and Basal Area Increment

Spacing significantly affected diameter growth.⁵ Trees at the widest spacing grew at the rate of 3.2 inches per decade compared with 2 inches where trees were spaced 13.2 feet apart (fig. 4). Released trees were evidently able to utilize the additional growing space shortly after thinning. For example, statistical tests indicate that differences between growth rates at the two widest spacings are real and not due to chance. Therefore, trees spaced at 18.7 feet are competing for soil moisture and nutrients only a few years after release.

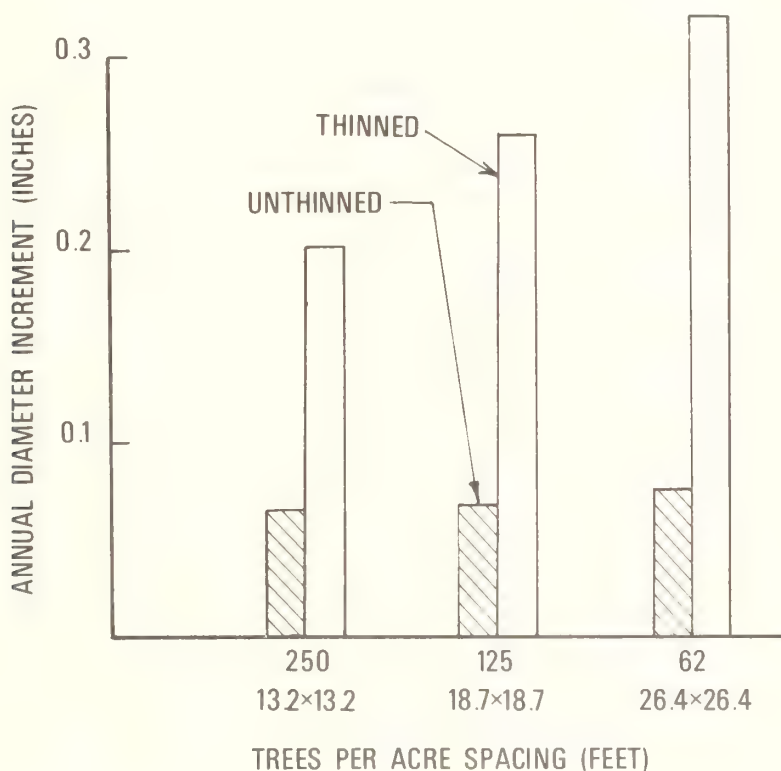


Figure 4.--Average annual diameter increment per tree in the thinned stand and average growth on a comparable number of trees in the control plot.

⁵ Analysis of variance and orthogonal comparisons included only plots at spacings of 13.2, 18.7, and 26.4 feet. Covariance was not used because individual tree increments failed to show any significant relation to diameter at the time of thinning.

The close spacing of the trees on the control plots did not allow even the best trees to grow at acceptable rates. Diameter increment from age 47 to 52 years was determined by boring the equivalent of 62, 125, 250, and 500 evenly spaced trees per acre on each of the control plots. The 62 trees per acre are growing only slightly better than where 250 trees were selected (fig. 4), indicating that even the largest trees are suffering badly from competition.

Substantial differences exist in tree growth between control plots and thinned plots. For example, the growth rate of the best 125 trees per acre on the control plots averaged only 0.7 inch per decade compared with 2.6 inches per tree per decade on plots thinned to this density.

Basal area on all trees in the check plots is increasing at the rate of about 6 square feet per acre per year. In contrast, thinned plots are adding basal area at the rate of 2.7 square feet at the narrowest spacing and only 1.4 square feet at the widest spacing. Trees spaced 18.7 feet apart are accumulating basal area at the rate of about 2 square feet with only 5 percent of the total number of trees on the check plots.

The relative increase in basal area from one spacing to another suggests that the potential for wood production recovers rapidly after initial reduction in growing stock. To illustrate, basal area where trees are spaced at 18.7 feet (table 1) has reached 27.1 square feet at age 52, which slightly exceeds 26.8 square feet at age 47 where twice as many trees were left (13.2 feet). The same relationships are present when only the two widest spacings are considered. Maybe thinned stands similar to the one described here can accumulate a level of growing stock equal to a stand with twice as many trees in only 5 years.

Height Increment

Height growth ranged from 1.3 feet per year on some individual trees to almost no detectable growth on a few trees in the control plots. Average annual height growths per tree for each treatment were as follows:

<u>Spacing</u> (Feet)	<u>Height</u> <u>growth</u> (Feet)
13.2	0.64
18.7	.72
26.4	.82

For trees of comparable initial diameter, height increments not differ significantly between spacings. Larger trees grew 1. in height than smaller trees. For example, where trees averaged

Table 1.--Average stand characteristics immediately after
thinning and 5 years later (per acre)

Spacing (feet)	Stand age	Average ^{1/} d.b.h.	Average ^{2/} height	Basal area	Volume ^{3/}
	<u>Years</u>	<u>Inches</u>	<u>Feet</u>	<u>Square feet</u>	<u>Cubic feet</u>
13.2	47	4.4	23.4	26.8	270
(250 trees per acre)	52	5.4	26.6	40.1	424
18.7	47	5.0	25.7	17.4	189
(125 trees per acre)	52	6.3	29.3	27.1	314
26.4	47	5.8	28.5	11.4	127
(62 trees per acre)	52	7.4	32.6	18.4	223
4.3	47	3.0	--	93.0	--
(Control, 2,356 trees per acre)	52	3.2	--	122.7	1,082

^{1/} Diameter of tree of mean basal area.

^{2/} Arithmetic mean.

^{3/} Volume of entire stem, inside bark.

4.5 inches in diameter at the time of thinning, height increment was 0.6 foot per year compared with 0.9 where trees averaged 6 inches in diameter (fig. 5). The lack of influence of tree competition or spacing on height growth during the last 5 years can be further illustrated by the fact that the 62 best trees per acre on the three closest spacings (including the control plots) grew as well as trees at the widest spacing.

Past stand density has probably influenced height growth as well as diameter growth. Thus, age is important, and we would surmise that earlier thinning could stimulate height growth.

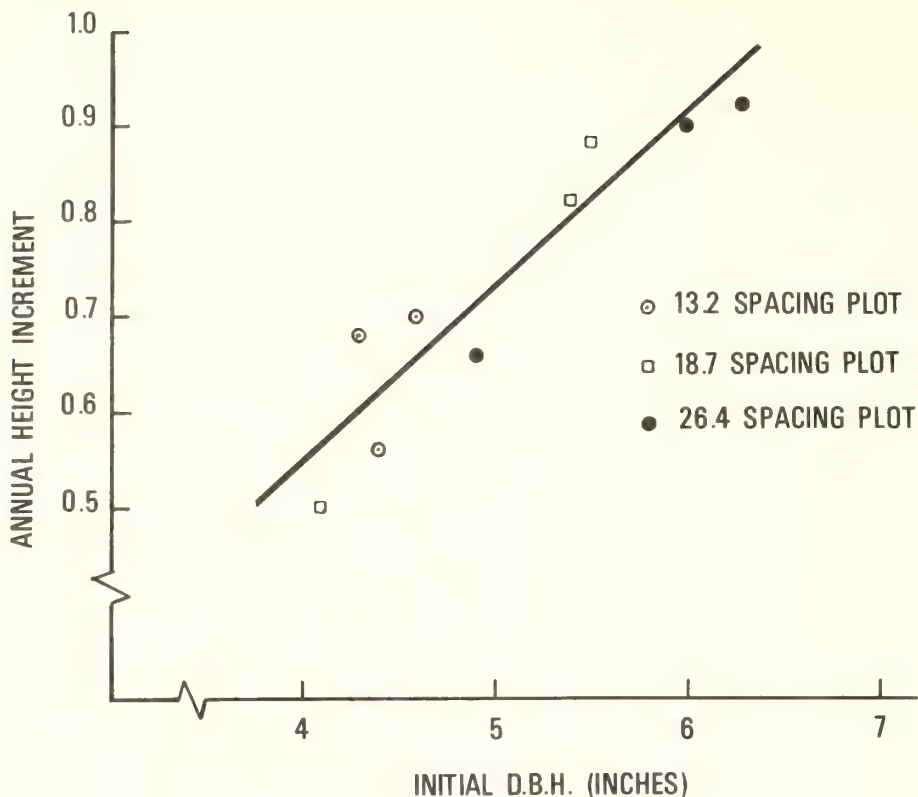


Figure 5.--*Relationship of average annual height increment to average diameter directly after thinning.*

Volume Increment

Where trees are widely spaced, some reduction in total wood production is evident. However, this reduction is not as great as some would expect (fig. 6). For example, where trees are spaced at 18.7 feet the stand is already growing 81 percent of that produced by a stand having twice as many trees (250 trees per acre). Therefore, a small sacrifice of presently unmerchantable fiber production has permitted wood accumulation on trees which are sure to reach merchantable size in less time than where a greater number of trees were left. Most of the productive capacity of the stand may recover rapidly where trees are spaced at 18.7 feet because basal area is already accumulating at the rate of 2 square feet per acre per year.

Volume increment was influenced by the size of tree that could be left. As tree size was partly a result of stand density prior to thinning, some plots having the same treatment had decidedly different average diameters after thinning. Larger trees for a given spacing

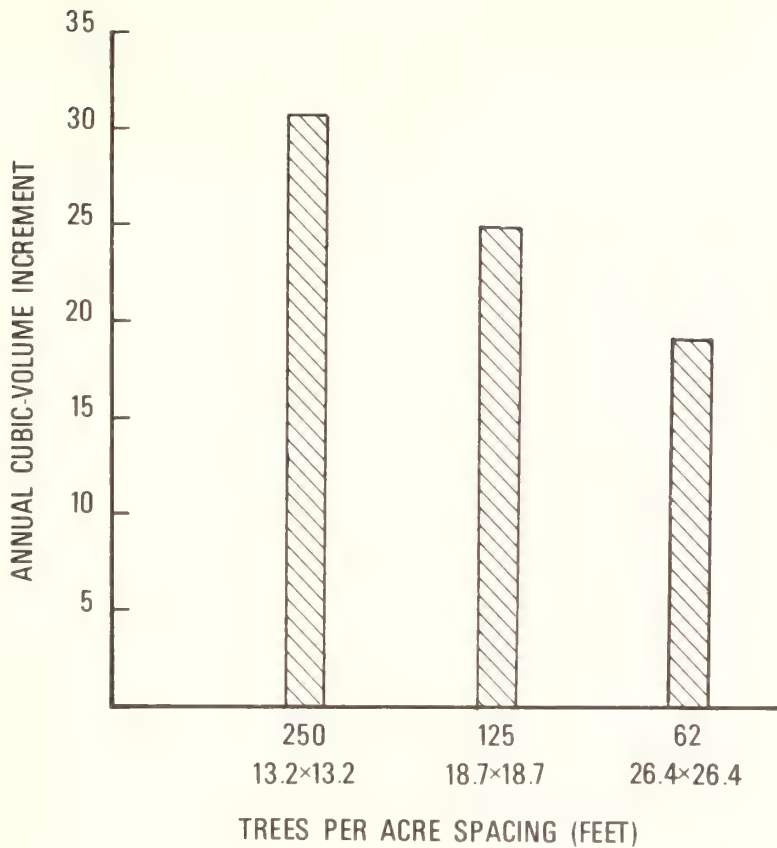


Figure 6.--Average annual cubic-volume increment at different spacings.

produced more volume. For example, with spacing held the same, a stand with an average diameter at the time of thinning of 6 inches produced twice as much volume as a stand averaging 5 inches in diameter.

Cubic-volume increment is well correlated with initial volume and basal area (fig. 7). Volume production is only about 15 cubic feet per acre per year where the stand was reduced to only 10 square feet of basal area per acre and a little over 30 cubic feet when cut back to 25 square feet of basal area.

Mortality

Almost no mortality is taking place in the unthinned stand. Furthermore, there is little evidence to indicate that any significant mortality has taken place for 20 years. The stand is remarkably free of insect activity and disease. No mortality was observed in the thinned stand.

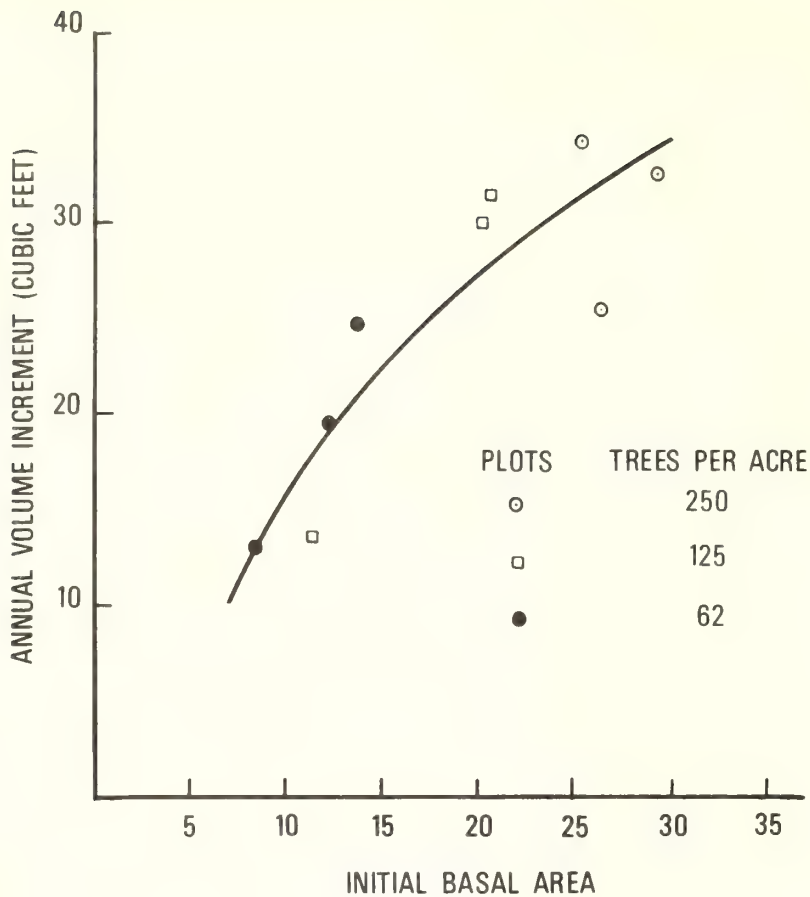


Figure 7.--*Relationship of average annual volume increment to basal area directly after thinning.*

Forage Production

McConnell and Smith⁶ reporting on forage production aspects of this study, three growing seasons after thinning, found understory yield greater on thinned than on unthinned plots. They also showed that as pine canopy and stand basal area decreased with wider spacing, understory yield was increased. In addition, when crown canopy exceeded 45 percent, forbs produced more than grasses, but below 45 percent, grasses were superior producers. Initial rates of increase in understory yield were small--2 pounds for each 1-percent decrease in canopy cover or

⁶ McConnell, Burt R., and Smith, Justin G. Understory response three years after thinning pine. *J. Range Manage.* 18: 129-132, illus. 1965.

square feet of basal area. However, these investigators believe additional growing seasons are needed for the productive capacity of the site to respond fully to timber stand treatment.

CONCLUSION

This experiment demonstrates that substantially greater diameter growth per tree and greater wood production on trees that will reach usable size may be attained by thinning site V ponderosa pine pole stands in northern Washington. Site not used by widely spaced young trees in the first years after thinning is at least partially utilized by understory vegetation. Thus, the usefulness of the forest is increased for wood and forage production.

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SOIL SURFACE TEMPERATURES ON CUTOVERS IN SOUTHWEST OREGON

by

William E. Hallin, *Principal Silviculturist*

ABSTRACT

Discusses soil temperatures one can expect on various micro and macro sites in southwest Oregon. Gives recommendations for harvest techniques on steep southerly slopes.

High soil surface temperatures are commonly recognized as a cause of conifer seedling mortality. Silen^{1/} has shown that soil surface temperatures lethal to Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings are common on cutover areas in the central Cascade Range of Oregon. Increased evaporation and transpiration due to high temperatures may also increase seedling mortality.

Heat as a factor in seedling mortality is a complex subject. Variation in survival of some seedlings and death of others continues to be perplexing. Silen has amply demonstrated that no single temperature can be considered lethal for Douglas-fir. Each seedbed type such as mineral soil or duff has a distinct killing temperature. Thus, seedlings might survive for hours under full exposure to sunlight in one seedbed and be killed in a few minutes on others. Even small amounts of shade at the base of a seedling stem are important to survival. Silen's studies showed no development of heat resistance

^{1/} Silen, R. R. Lethal surface temperatures and their interpretation for Douglas-fir. 170 pp. 1960. (Unpublished Ph.D. thesis on file at Oreg. State Univ., Corvallis.)



with age in a seedling. Keijzer and Hermann^{2/} did demonstrate that such resistance appeared to develop in explanation of variation found in the field.

Franklin^{3/} observed that rather large numbers of Douglas-fir seedlings in the central Cascades do survive after exposure to sunlight for many hours without stand-edge shade. Thus, it would appear from cited studies that it is not essential that every square foot of a clearcut be fully protected from excessive surface heat and that any substantial alleviation of midday heat problem may be enough to get minimum acceptable levels of stocking under southwestern Oregon conditions.

Simple exploratory studies reported here were conducted to help delineate the problem concerning heat and mortality of seedlings in southwestern Oregon.

METHODS

Influence of elevation, slope and aspect, low objects, timber edge, and time of day on soil surface temperatures was explored by use of commercial temperature pellets (Tempils).^{4/} Tempil melting points were 113°, 125°, 138°, 150°, 163°, 175°, and 188° Fahrenheit. At each sampling point, highest temperature attained was indicated in 12° or 13° intervals by a melted Tempil and was recorded as range in temperature. For example, 125°-138° indicates that maximum temperature was 125° or higher but less than 138°. Tempils were broken in half and inserted vertically in soil to assure that ground-line temperatures were recorded.

^{2/} Keijzer, Steven de, and Hermann, Richard K. Effect of environment on heat tolerance of Douglas-fir seedlings. Forest Sci. 12: 211-212. 1966.

^{3/} Franklin, Jerry F. Natural regeneration of Douglas-fir and associated species using modified clearcutting systems in the Oregon Cascades. U.S. Forest Serv. Res. Pap. PNW-3, 14 pp., illus. 1963.

^{4/} Silen, Roy R. Use of temperature pellets in regeneration research. J. Forest. 54: 311-312., illus. 1956.

Elevation.--Temperatures were measured (August 1964) in the upper South Umpqua drainage at 10 locations ranging from 1,850 to 5,000 feet in elevation (elevations from U.S. Geological Survey maps). Tempils were placed in boxes of fine, light-colored, beach sand at each location. Sand was used in order to eliminate variation in heating rate that might occur in the soils at the sampling location. Sand boxes were placed on level, unshaded spots with sand surface flush with natural ground surface. At four locations, Tempils were also placed in unshaded mineral soil near the sand boxes.

Slope and aspect.--Temperatures were measured (August 1964) at the surface of inclined boxes of soil on a level area at the Pacific Northwest Forest and Range Experiment Station's Roseburg laboratory site. River loam, sifted through a 20-mesh screen, was placed in conventional greenhouse flats and compacted by wetting. When the soil appeared dry, pairs of boxes were installed on inclined frames with 25-percent, 50-percent, 75-percent, and 100-percent slopes. One of each pair faced due north and the other due south. In addition, two boxes were placed with no slope--one box on the ground and the other set on a light, wood frame approximately 1 foot above soil surface. Two sets of Tempils were inserted in each box.

Shade from low objects.--Soil surface temperatures in a clearcut were measured (June and July 1962) near low objects on a steep (60-70 percent) west slope (10° south of west). Microsites, sampled with two replications each, were unshaded bare ground, north and south side of logs, north side of shingles approximately 3 inches wide, under grass, and at base of deerbrush (*Ceanothus integerrimus*) approximately 2 feet high and 2 feet across.

Timber edge.--Soil surface temperatures were measured (summer 1964) along four lines at right angles to an east and west edge of the clear-cut. Strips were approximately 1 chain apart. Tempils were placed at $\frac{1}{2}$, 1, 2, 3, 4, and 5 chains north of the timber edge in bare mineral soil. All objects, other than trees, that would shade the Tempil locations were removed. Ground sloped gently east and northeast.

Time of shade.--On July 29, 1965, effect of shade duration on surface temperature was measured on a level area at the Roseburg laboratory site. Shade was provided with grocery packing cartons approximately 12 to 18 inches on a side. A small hole at the bottom of the south side and the entire north side of each carton was cut out to provide for air circulation. Tempils were placed in dry river loam soil in cigar boxes under the cartons. Cartons were systematically removed to expose the Tempils for all multiples of 2 hours for the period 0700 to 1700 (true or solar time), starting with the period 0700 to 0900. Thus, cumulative temperature records were taken for 15 different 2-hour, or multiple of 2-hour, periods that soil was exposed to full sunlight.

Shadow length and direction.--Length and direction of shadows were computed from astronomical formula and data for June 21 at 42°30' latitude for each hour of solar time from 0700 to 1700. Shadow distance at right angle to timber edges and percentage of surface of clearcut strips of different widths were also computed.

RESULTS

Temperatures reported here are maximum with no measure of the time they persisted. Where a range is given, temperature was above the lower value and below the higher value.

Elevation.--In the period July 23 to September 1, 1964, elevation had no effect on maximum surface temperature of sand in small boxes set in the ground at elevations of 1,850 to 5,000 feet, as recorded with Tempils. During the period July 23 to July 30, maximum observed surface temperatures were either slightly below or slightly above 138° F. Temperatures above and below 138° F. were observed over the complete range of elevations sampled. During the period August 18 to September 1, maximum surface temperatures at all sampling points were between 125° and 138° F. Maximum surface temperature of unshaded mineral soil was the same as for sand.

Slope and aspect.--As expected, maximum soil surface temperatures increased as slope percent increased on south aspects and decreased as slope percent increased on north aspects (fig. 1). During the period August 5 through August 24, 1964, maximum surface temperatures on inclined boxes of soil were as follows:

<u>Slope</u> (Percent)	<u>Aspect</u>	<u>Maximum temperature</u> (Degrees F.)
100	North	Less than 113
75	North	125 - 138 ^{1/}
50	North	125 - 138
25	North	125 - 138
0		125 - 138 ^{2/}
25	South	138 - 150
50	South	138 - 150
75	South	150 - 163
100	South	150 - 163

^{1/} Condition of Tempils suggested that temperature was closer to 125° than 138°. In this case, most of the 125° F. pellet remained unmelted.

^{2/} Condition of Tempils suggested that temperature was closer to 138° than 125°. In this case, all the 125° F. pellet had melted.

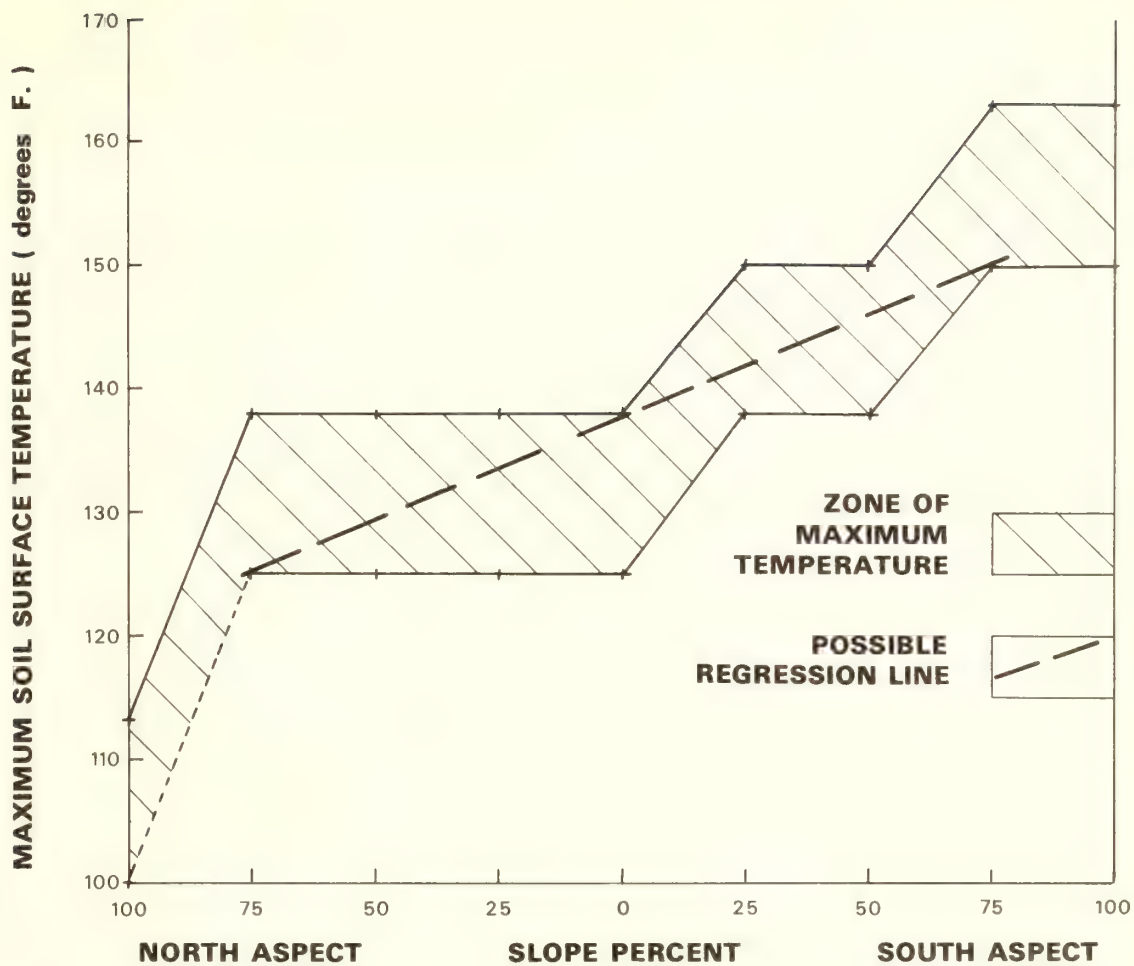


Figure 1.--Influence of slope and aspect of inclined boxes of river loam on maximum soil surface temperatures August 5 to August 25, 1964.

On figure 1, an approximate regression line indicating a change of 1.7° F. per 10-percent change in slope can be drawn in the zone of maximum temperature between 75-percent north slope and 75-percent south slope. Data suggest that maximum surface temperatures on south aspects become constant at slopes above 75 percent but decrease at a faster rate on slopes above 75 percent on north aspects.

Maximum surface temperatures on the level soil box raised 1 foot above the ground were between 125° and 138° F., whereas those on the box flush with the ground were between 138° and 150° F. Therefore, it is probable that maximum soil surface temperatures on natural ground slopes were higher than those observed on inclined boxes.

Shade from low objects.--On steep westerly slopes, shade from logs, shingles, and vegetation reduced maximum temperatures on soil surfaces, but not below 138° F. except under deerbrush. In the period June 26 to August 1, 1962, maximum soil surface temperatures on a steep westerly facing clearcut were as follows:

	<u>Sample point 1</u> (Degrees F.)	<u>Sample point 2</u> (Degrees F.)
Unshaded	163 - 175	175 - 188
South side of log	163 - 175	175 - 188
North side of log	138 - 150	150 - 163
North side of shingle	150 - 163	150 - 163
Under grass	163 - 175	175 - 188
Base of deerbrush	125 - 138	125 - 138

Soil surfaces were bare except under grass where grass litter was present.

East and west timber edge.--Shade from an east and west timber edge on the south side of a clearcut (July and August 1964) reduced maximum soil surface temperatures for a distance of less than 1 chain into the clearcut. Maximum surface temperatures at one-half chain were less than those at 1 chain for 14 out of 17 observations. At 1 chain and beyond, temperatures were essentially the same. During midday, 1/2-chain points were always shaded, whereas points 1 chain and beyond were never shaded. Average height of dominant trees along or near the timber edge was 140 feet.

Time of shade.--Among combinations of full exposure for various periods, shading soil surfaces before 1100 and after 1500 had little effect on maximum temperatures (table 1). In all cases where soil was exposed to full sunlight from 1100 to 1500, maximum surface temperature was between 138° and 150°, regardless of whether or not surface was exposed to full sunlight before 1100 or after 1500. The period 1100 to 1300 was most important for attaining maximum temperatures, as sun between 1300 and 1500 increased maximum temperature only a few degrees.

Table 1.--Effect of time of day and duration of full sunlight
on river loam soil surface temperatures^{1/}

Duration of exposure to full sunlight	Temperature rating by Tempil melting points ^{2/} at designated solar times				
	0900	1100	1300	1500	1700
	----- Degrees F. -----				
0700 to 1700	<113	125S	138S	138M	138M
0700 to 0900	<113	<113	<113	<113	<113
0700 to 1100	<113	125S	(3/)	(3/)	125M
0700 to 1300	<113	125S	138S	(3/)	138S
0700 to 1500	<113	125S	138S	138M	138M
0900 to 1100	<113	125S	(3/)	(3/)	125M
0900 to 1300	<113	125S	138S	(3/)	138S
0900 to 1500	<113	125S	138S	138M	138M
0900 to 1700	<113	125S	138S	138M	138M
1100 to 1300	(3/)	<113	138S	(3/)	138S
1100 to 1500	(3/)	<113	138S	138M	138M
1100 to 1700	(3/)	<113	125G ^{4/}	138S	138S
1300 to 1500	(3/)	(3/)	<113	125G	125G
1300 to 1700	(3/)	(3/)	<113	125G	125G
1500 to 1700	(3/)	(3/)	(3/)	<113	113M

^{1/} July 29, 1965, at Roseburg--maximum air temperature, 93° F.
All time is true or solar time.

^{2/} S, pellet slightly melted; M, approximately one-third to
one-half melted; G, pellet completely melted.

^{3/} No reading.

^{4/} Partial shade from windblown box.

Shadow length and direction.--Computations show that clearcut
strips or patches must be quite narrow if an appreciable percentage of
the soil surface is to be shaded during hot midday periods.

Shadow length (fig. 2, table 2) as percent of tree height and di-
rection were computed for different hours from following formulas:

$$1. \text{ Sine } \alpha = \text{cosine } d \times \text{sine } H \times \text{cosine } L + \text{sine } L \times \text{sine } d$$

$$2. \text{ Cosine } z = \text{tangent } \alpha \times \text{tangent } L - \frac{\text{sine } d}{\text{cosine } \alpha \times \text{cosine } L}$$

$$3. \frac{S}{h} \times 100 = \cotangent \alpha \times 100$$

where:

α = angle of sun's altitude

d = sun's declination as determined from a solar ephemeris

L = latitude

H = sun's hour angle measured from 0600 solar time
(15° per hour)

z = sun's bearing measured from south

S = shadow length cast by border trees

h = height of border trees

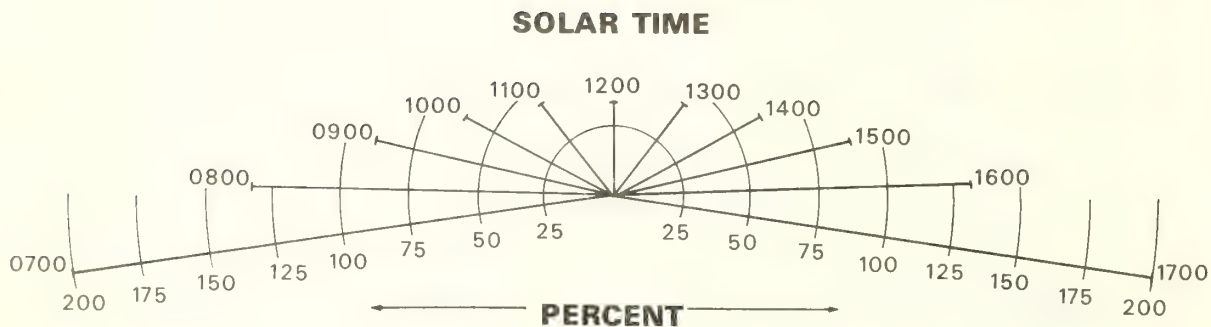


Figure 2.--Shadow direction and length as percent of tree height; June 21, lat. $42^\circ 30'$.

Table 2.--*Relative length and direction of tree**shadows, June 21, latitude 42°30'*

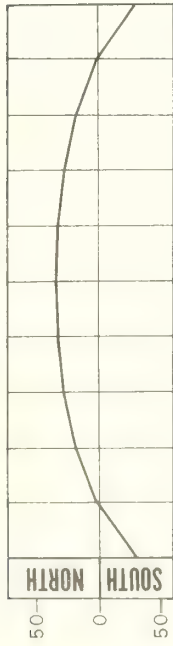
Sun time	: Bearing from north	: Length as percent of tree height
0700	98°28' W.	201.9
0800	88°48' W.	130.9
0900	77°25' W.	89.0
1000	62°03' W.	60.8
1100	37°52' W.	41.9
1200	0°	34.5
1300	37°52' E.	41.9
1400	62°03' E.	60.8
1500	77°25' E.	89.0
1600	88°48' E.	130.9
1700	98°28' E.	201.9

Shadow distances at right angles to timber edges running NW.-SE., NE.-SW., N.-S., and E.-W. were computed from shadow length and direction and sun's angle to timber edge for various hours of the day (fig. 3). Computations were made for June 21, the day with the shortest shadows, and for latitude 42°30', approximate midlatitude for the mixed pine-fir type in southwestern Oregon. Shadows for a 100-foot tree are only 3 feet longer at noon on June 1 and July 12 than on June 21; hence, there is a 40-day period when changes in shadow length are small.

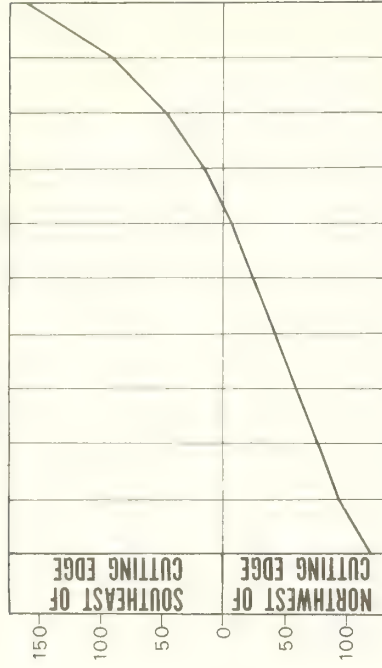
With data on shadow distance measured at right angles to cutting edge, percentage of clearcut strips shaded was computed for hourly intervals from 0700 to 1700 (figs. 4, 5, 6, 7; table 3). Area shaded at ends of strips was ignored because the purpose is to show effect of strip width. Strip widths equal to 50 percent, 100 percent, and 200 percent of border-tree heights were used.

Average effective tree height for shading clearcuts is less than average height of dominant trees because of undulating level of the crown canopy along a timber edge. Average effective tree height for casting shadows from timber edges also varies with density of the remaining stand along timber edge. The minimum reduction from actual average tree height that should be used is probably 10 feet.

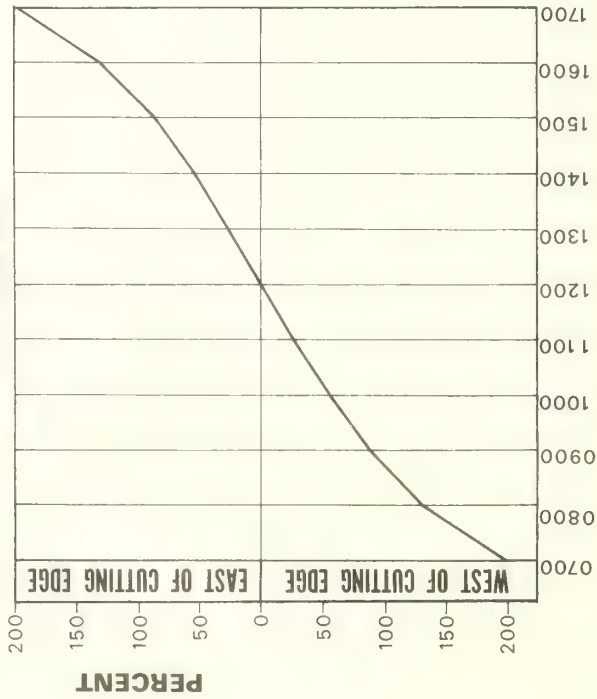
EAST AND WEST STRIP



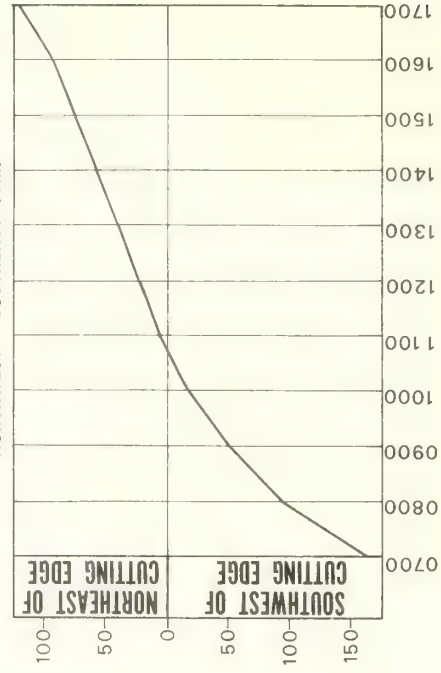
NORTHEAST - SOUTHWEST STRIP



NORTH - SOUTH STRIP



NORTHWEST - SOUTHEAST STRIP



SOLAR TIME

Figure 3.--Shadow distance at right angle to timber edges as percent of border tree height, by time of day, June 21, lat. 42°30'.

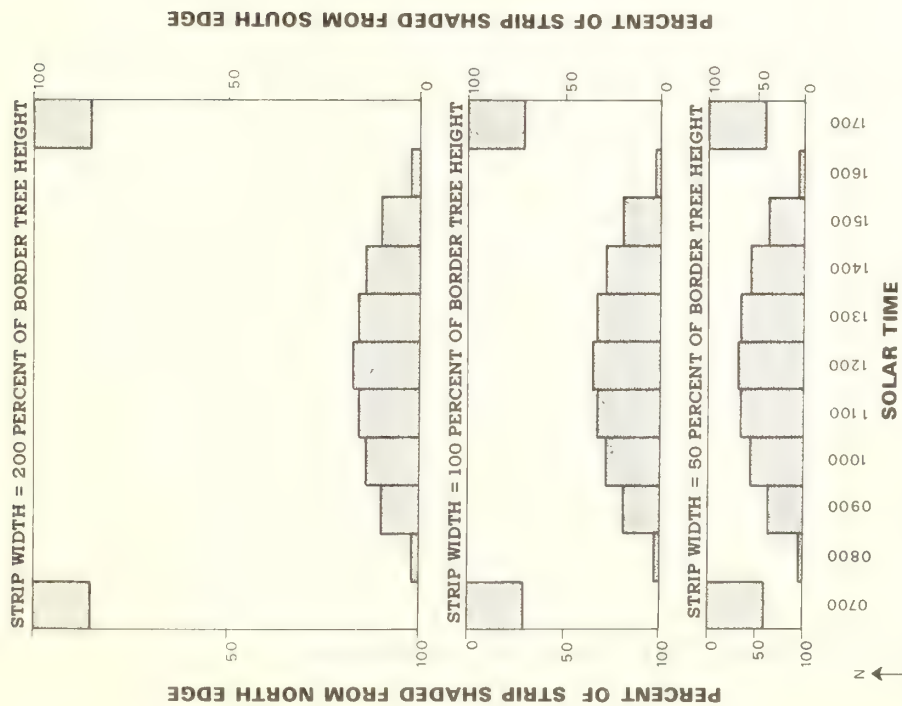


Figure 4.--Percent clearcut strip width shaded. East-west strip, June 21, lat. 42°30'.

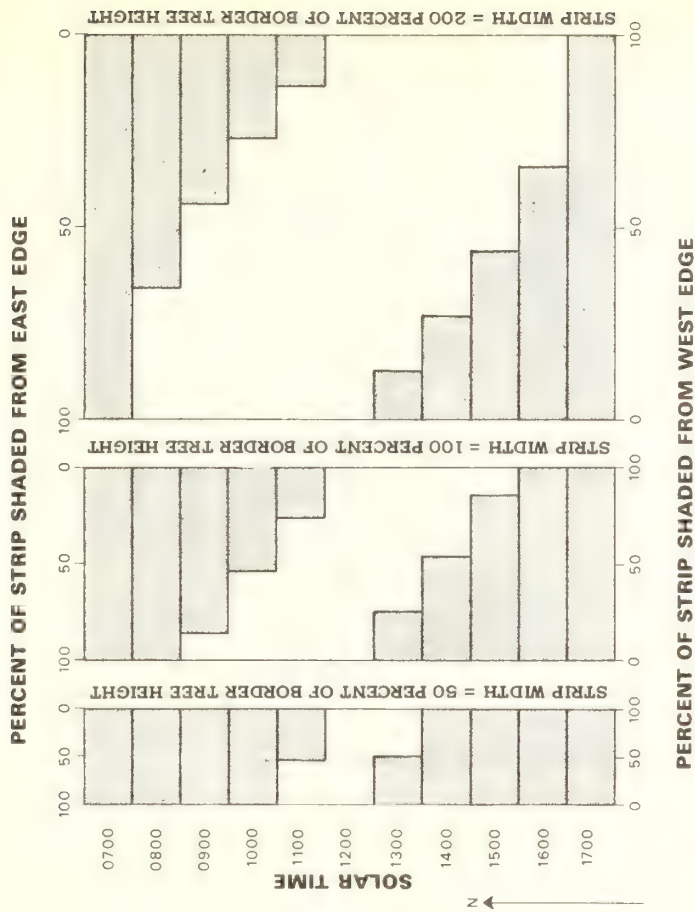


Figure 5.--Percent clearcut strip width shaded. North-south strip, June 21, lat. 42°30'.

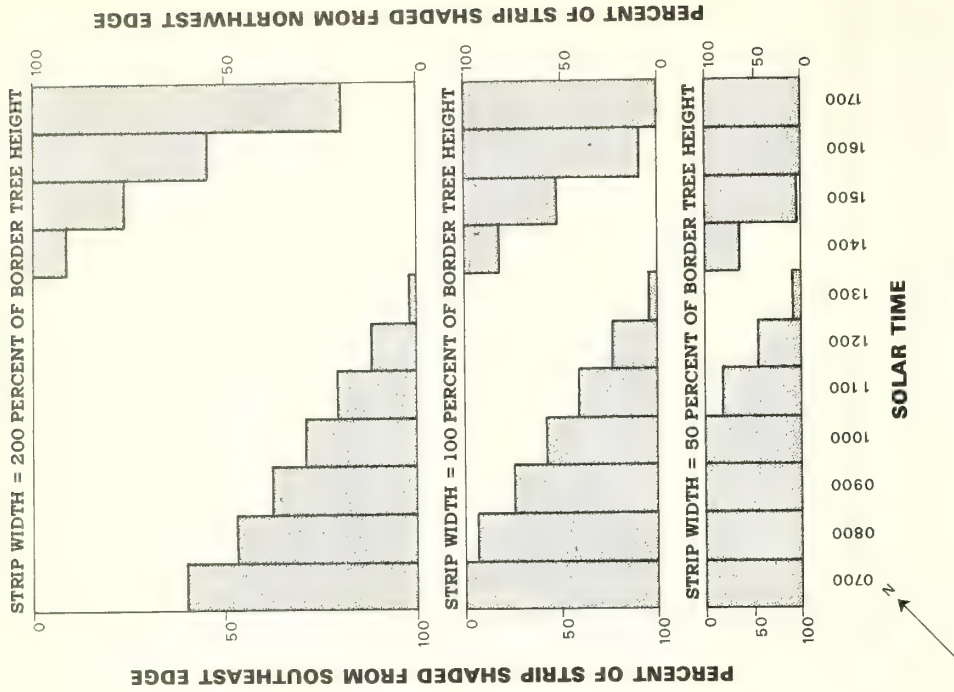


Figure 7.---Percent clearcut strip width shaded. Northeast-southwest strips, June 21, lat. 42°30'.

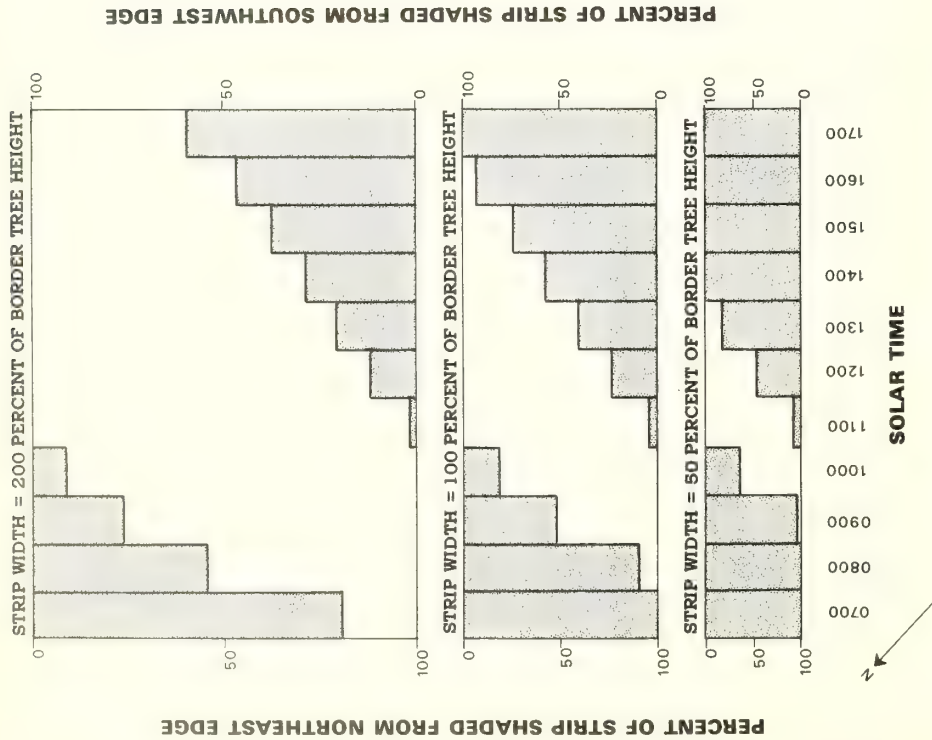


Figure 8.---Percent clearcut strip width shaded. Northwest-southeast strips, June 21, lat. 42°30'.

Table 3.--Percent of clearcut strip width shaded by time of day
and by strip direction, for strips of three relative
widths, June 21, lat. $42^{\circ}30'$

Strip direction	Solar time										
	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700
<u>Strip width equal to 50 percent of border tree height</u>											
NW.-SE.	100	100	96	36	10	48	84	100	100	100	100
NE.-SW.	100	100	100	100	84	48	10	36	96	100	100
N.-S.	100	100	100	100	52	0	52	100	100	100	100
E.-W.	60	6	38	56	66	68	66	56	38	6	60
<u>Strip width equal to 100 percent of border tree height</u>											
NW.-SE.	100	91	48	18	5	24	42	58	75	94	100
NE.-SW.	100	94	75	58	42	24	5	18	48	91	100
N.-S.	100	100	87	54	26	0	26	54	87	100	100
E.-W.	30	3	19	28	33	34	33	28	19	3	30
<u>Strip width equal to 200 percent of border tree height</u>											
NW.-SE.	81	46	24	9	2	12	21	29	38	47	60
NE.-SW.	60	47	38	29	21	12	2	9	24	46	81
N.-S.	100	66	44	27	13	0	13	27	44	66	100
E.-W.	15	2	10	14	16	17	16	14	10	2	15

When strip width equals 50 percent of border tree height, none of north-south and only 16 percent of northwest-southeast clearcut strips are exposed to full sunlight for 2 hours or more during the critical period 1100 to 1500 (table 4).

Table 4.--Percent of width of clearcut strips exposed to full sunlight 2 hours or more during period 1100 to 1500, June 21, lat. $42^{\circ}30'$

Strip direction	Strip width as percent of border tree height		
	50	100	200
North-south	0	74	87
Northwest-southeast	16	58	79
East-west	34	67	83
Northeast-southwest	80	95	97

DISCUSSION AND CONCLUSIONS

Exploratory studies for southwest Oregon, reported in this paper, are backed up by cited studies in the Cascade Range of Oregon and bring out a consistent picture. Southwest Oregon situations appear to be somewhat more extreme in that higher maximum temperatures were found than in other studies. For example, 175° F. recorded in southwest Oregon was higher than the highest temperature found by Silen in the Oregon Cascades. Hence, general conclusions for the Pacific Northwest region, regarding need for reduction of surface temperatures, are more acute in southwest Oregon.

Interplay of several factors must be kept in mind in developing any recommended practice for reduction of seedling mortality from high surface temperatures. Silen^{5/} has shown that lethal seedbed surface temperatures vary with duration and kind of seedbed surface. For example, more than 4 hours of exposure to 130° F. are required to kill in most easily heated seedbeds. At 150° F., on the other hand, about 15 minutes of exposure are required to kill in a litter type of seedbed characterized by peat moss, whereas seedlings survive about 1 hour in yellow mineral soil. At 138° F., the temperature used in this paper to characterize

^{5/} See footnote 1.

mortality, the corresponding durations of exposure for mortality are about 1 hour in peat moss and 4 hours in yellow mineral soil. Thus, it becomes apparent that more extreme temperature conditions in southwest Oregon make need for shade more critical.

Another factor is that natural variation on clearcuts appears to provide a percentage of microsites that never reach lethal temperatures. The proportion is small on south slopes but rises on more favorable northerly aspects.

Within this general framework, results of exploratory studies reported here suggest some tentative recommendations for southwest Oregon.

In the South Umpqua drainage, maximum summer temperatures on unshaded soil surfaces normally are in excess of 138° F. On steep southwesterly slopes, maximum surface temperatures in excess of 175° F. have been measured and are usually considerably in excess of 138° . Data from inclined boxes and field measurements indicate that maximum surface temperatures on unshaded soil on level and north aspects commonly are not greatly in excess of 138° , and on steep north slopes may be less than 138° . Thus, shade from low objects like logs, chunks, or shingles won't reduce maximum soil temperatures below lethal levels on southerly and westerly aspects, but usually will on northerly slopes. Furthermore, under the same sun, shade from low objects on north slopes will cover a greater area than on south slopes. On southerly aspects, additional high shade is probably necessary in order to prevent heat-killing of new seedlings.

Shade may be necessary for establishment of natural regeneration at all elevations in the South Umpqua drainage, since maximum soil surface temperatures may exceed 138° F. at all elevations up to 5,000 feet.

On the basis of the 2-hour temperature measurements on level ground, it would appear that critical time to have full shade would be between 1100 and 1500. Temperatures of fully exposed level surfaces were only slightly above 125° F. up to 1100. Maximum temperatures between 138° and 150° were reached on all surfaces fully exposed between 1100 and 1500, regardless of whether or not they were shaded before 1100. Additional sunlight between 1300 and 1500 increased maximum temperatures only slightly over those already reached on areas exposed to sun between 1100 and 1300. However, shade between 1300 and 1500 is very important, as it will reduce duration of maximum temperatures.

An increase in temperature increases transpiration and, therefore, contributes to drought-caused mortality. Periods of shade at any time of the day may be helpful in reducing drought-caused mortality of planted trees, especially on southerly and westerly aspects.

Additional high shade to supplement low shade may be provided by partial or strip cutting. Partial cutting is now used quite extensively in southwest Oregon on areas where topography is suitable for tractor logging. Apparently, adequate shade for successful establishment of reproduction is being provided. However, with presently available logging equipment, it is not practical to make extensive partial cuts on steep slopes with low volumes of timber. Although strips can be logged with high lead on steep slopes, narrowness of strip needed for optimum shade prevents economical logging.

Data for shadow length and direction show that width of clearcut strips must not exceed approximately 50 percent of effective border-tree height to lower maximum soil surface temperatures and thus reduce killing of new seedlings.^{6/} For example, regardless of orientation, over 50 percent of strip width is exposed to 2 hours or more of direct sunlight in the critical period 1100 to 1500 if strip width is equal to 100 percent of border-tree height. If strips are 50 percent of tree height, orientation in any direction except northeast and southwest is suitable (table 3). However, if north-south strips are used, cutting of adjacent strips must be delayed until the new crop of trees is tall enough to cast shade an effective distance. With east-and-west or northwest-southeast strips, midday shade comes from south or southwest sides. Consequently, the next strip can be cut as soon as regeneration is established on the first strip.

Width of strips needed to provide shade to prevent heat-killing of new seedlings varies with slope, aspect, and direction of strip as well as border-tree height. However, in southwestern Oregon, clearcut strip widths needed to provide adequate shade to prevent heat-killing of new seedlings usually will be approximately 1 chain or less, as tree height commonly is 150 feet or less on southerly aspects where heat-killing is critical. Thus, 50 percent of effective tree height is commonly 70 feet or less if effective tree height is 10 feet less than actual height. With presently available logging equipment, it usually is not practical to use strips as narrow as one chain in harvesting timber on steep southerly slopes.

^{6/} In this discussion, unless otherwise specified, reference is made to level areas, June 21, and latitude 42°30'. Shadows from southerly timber edges are shorter on south slopes and longer on north slopes than on level ground.

RECOMMENDATIONS

The following recommendations for southwest Oregon are made for areas on which high surface temperatures are an important cause of seedling mortality:

1. Wherever tractor logging is suitable, harvest timber with a partial cut or with strips not wider than 50 percent of border-tree height, but avoid strips oriented northeast-southwest.
2. Hold to a minimum timber harvesting on southerly slopes too steep for tractor logging until equipment is developed that will permit economic logging of low volumes of timber on narrow strips or partial cuts.
3. Development of logging equipment that will permit economic harvesting of low volumes of timber on steep slopes for partial cuts or narrow strips should be expedited.
4. In the interim, whenever it is necessary to harvest timber on steep southerly slopes--
 - a. Clearcut strips or units should be as narrow as practical.
 - b. Northeast-southwest oriented strips or clearcut units should be avoided if possible.
 - c. A lower standard of stocking and a longer regeneration period should be accepted.
 - d. Wherever it is not essential to burn the slash, trees should be left standing in lanes radiating from the spar pole.

Pacific
North
West Forest and Range Experiment Station
Forest Service **RESEARCH NOTE**

PNW-79

May 1968

ENZYME NITRATE REDUCTASE OF SOME PARASITIC FUNGI

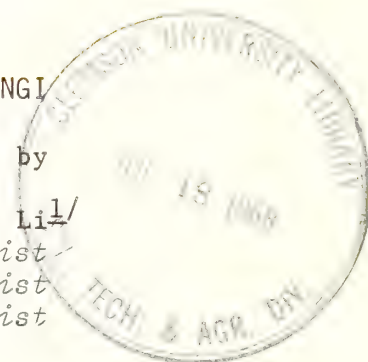
by

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K. C. Lu, Microbiologist

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ABSTRACT

Eight parasitic fungi, *Fusarium avenaceum*, *F. oxysporum*, *Gliocladium roseum*, *Phytophthora cinnamomi*, *Pythium debaryanum*, *Poria weirii*, *Trichothecium roseum*, and *Verticillium alboatrum*, were grown in liquid culture to determine the ability of each to produce nitrate reductase, an enzyme necessary to convert nitrate nitrogen into the more easily used ammonium form.

Cell-free enzyme preparations from the eight fungi (and from *Neurospora crassa* as a check) were made after 2 weeks' growth and assayed for nitrate reductase activity. Apparently all fungi tested except *Poria weirii* produced the enzyme.

Inability of *Poria weirii* to produce nitrate reductase could have important implications in the biological control of this important forest root pathogen.

^{1/} Research assistant, Department of Microbiology, Oregon State University, Corvallis. Research was supported in part by National Science Foundation Grant No. GB-6191 and done in partial fulfillment of the requirements for a doctoral degree.

Many microorganisms use nitrate as their major source of nitrogen, converting it to ammonium forms or amino acids for protein synthesis. Some anaerobic organisms, moreover, employ nitrate as a terminal electron acceptor in place of oxygen, an energy-yielding reaction ("nitrate respiration") necessary for growth. The enzyme nitrate reductase, which is required as a catalyst for nitrate reduction, was originally partially purified and characterized from *Neurospora crassa* Shear and Dodge.^{2/} In an earlier study,^{3/} we found that *Poria weirii* Murr., a common root pathogen of many western conifers, lacks nitrate reductase and cannot assimilate nitrate. Since then, we have examined additional, hitherto untested, fungal parasites for nitrate reductase.

These fungi were obtained from the American Type Culture Collection:

Fusarium avenaceum 8150
Fusarium oxysporum 659
Gliocladium roseum 10521
Phytophthora cinnamomi 10922
Pythium debaryanum 9998
Trichothecium roseum 12519
Verticillium alboatrum 13642

We also retested *Poria weirii*, using the same isolate as before, because our technique had been modified for greater sensitivity in detecting nitrate reductase. *Neurospora crassa* was used as a check organism.

The isolate of each species was grown aerobically in three replicate 500-milliliter flasks containing 250 milliliters of synthetic medium on a reciprocating shaker in darkness at 24° C. The medium developed by Trione^{4/} was used, except that 10 grams glucose were included as a carbon source rather than 20 grams sucrose, and 0.1 percent potassium nitrate was added to the medium. L-asparagine was omitted for all but *Poria weirii*, which did not grow with KNO₃ as the only nitrogen source.

^{2/} Nason, A., and Evans, H. J. Triphosphopyridine nucleotide nitrate reductase in *Neurospora*. J. Biol. Chem. 202: 655-673. 1953.

^{3/} Li, C. Y., Lu, K. C., Trappe, J. M., and Bollen, W. B. Selective nitrogen assimilation by *Poria weirii*. Nature 213: 814. 1967.

^{4/} Trione, E. J. Isolation and *in vitro* culture of the wheat bunt fungi *Tilletia caries* and *T. controversa*. Phytopathology 54: 592-596. 1964.

After 2 weeks, mycelia of two replicate flasks were collected in a Buchner funnel, washed with ice-cold, glass-distilled water, and ground with 90-mesh alundum powder for 30 minutes in a cold mortar. The resulting material was ground for 10 minutes with five times the cell weight of cold 0.1 molar phosphate buffer (pH 7.1), then centrifuged at 0° C. for 20 minutes at 2,000 gravity. The sediment was discarded and the supernatant recentrifuged at 0° C. for 40 minutes at 20,000 gravity. The cell-free extract segregated by the second centrifuging was used in determination of enzyme activity. The remaining cultures were harvested at the same time; the mycelia were dried at 85° C. for 1 day and weighed. These dry weights provided a basis for expressing enzyme activity.

Enzyme activity was determined by the procedure of Egami and Taniguchi.^{5/} One milliliter of cell-free extract was incubated anaerobically for 8 hours at 27° C. in mixture with 0.5 milliliter flavin adenine dinucleotide-formate and 2.0 milliliter of 0.01 molar KNO₃ (the 2-hour incubation period used by Egami and Taniguchi proved inadequate for the organisms we studied). Colorimetric determination of nitrite formed during incubation, a reaction requiring nitrate reductase as a catalyst, then provided an index of nitrate reductase present in the cell-free extract. The activity was expressed as μ moles of nitrite per milligram of dry mycelium.

This method for determining nitrate reductase activity uses nitrate as a hydrogen acceptor, the nitrate serving as a terminal oxidant for a reduced intermediate. Because inorganic nitrate provided the sole nitrogen source for all cultures except *P. weirii*, positive results indicate functioning systems for nitrate assimilation.

Of the fungi tested, all but *P. weirii* produced nitrate reductase (table 1). Organisms must produce nitrate reductase to assimilate nitrate nitrogen. Hypothetically, relative efficiency in synthesizing this enzyme influences an organism's ability to compete for available nitrogen. If true, this hypothesis has important implications for biological control of pathogens in soil through control of kinds and amounts of available nitrogen.

We thank Dr. Earl Nelson, Forestry Sciences Laboratory, Forest Service, U.S.D.A., Corvallis, Oregon, and Dr. William H. Brandt, Department of Botany and Plant Pathology, Oregon State University, for cultures of *Poria weirii* and *Neurospora crassa*, respectively.

^{5/} Egami, F., and Taniguchi, S. Nitrate. In Methods of enzymatic analysis. Ed. by Hans-Ulrich Bergmeyer. Pp. 636-639. New York: Academic Press. 1963.

Table 1.--Nitrate reductase activity of cell-free extracts from two replicate cultures each of selected fungi, expressed as μ moles of nitrite formed per milligram of dry mycelium after incubation of crude enzyme extract with 2 milliliters of 0.01 molar KNO_3 and 0.5 milliliter FAD-formate solution

Fungus	Nitrite formed	
	Per replicate	Mean
	- - μ moles $\times 10^{-2}$ per mg. mycelium - -	
<i>Fusarium avenaceum</i>	0.547 .564	0.556
<i>Fusarium oxysporum</i>	.215 .224	.220
<i>Gliocladium roseum</i>	8.110 8.110	8.110
<i>Neurospora crassa</i>	4.600 4.600	4.600
<i>Phytophthora cinnamomi</i>	.476 .529	.503
<i>Pythium dearyanum</i>	1.210 1.210	1.210
<i>Poria weirii</i>	0 0	0
<i>Trichothecium roseum</i>	.632 .469	.551
<i>Verticillium alboatrum</i>	.155 .155	.155

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Northwest
Forest and Range Experiment Station
Forest Service **RESEARCH NOTE**

PNW-80

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TWO TESTS OF WHITE PINE, TRUE FIR, AND DOUGLAS-FIR
SEEDSPOTTING IN THE CASCADE RANGE

by

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ABSTRACT

Satisfactory stocking was obtained on seedspots protected by wire screens but generally not on unscreened spots despite extensive baiting of study areas. Western white pine was most successful species used and true firs were least successful. Damping-off, rodents, and insects were responsible for most seedling mortality.

Natural regeneration on high-elevation clearcut areas in the Pacific Northwest is often too slow or of undesirable species. A dependable method of artificially regenerating such areas is needed. Seedspotting offers one possibility; compared with broadcast seeding, it requires fewer seeds. By seedspotting, foresters can avoid some difficulties associated with high-country planting--a short, undependable planting season, heavy winterkill of fall-planted seedlings, and slow growth of planted trees.

This research note concerns two small-scale seedspotting studies. One study compared screened and unscreened seedspots and two species, western white pine (*Pinus monticola*) and either noble fir (*Abies procera*) or Shasta red fir (*A. magnifica* var. *shastensis*). Untreated and endrin-treated^{1/} Douglas-fir (*Pseudotsuga menziesii*) and Shasta red fir seed were compared in the second seedspot test as well as the effect of shading and screening seedspots.

Study Areas

Study plots were located on three recently logged, high-elevation areas in the Cascade Range--near Lost Creek, Mount Adams District, Gifford Pinchot National Forest, and on Red Blanket Mountain and at Lusby Cabin, Prospect District, Rogue River National Forest. Characteristics of the clearcuts are tabulated in table 1. To control seed-eating rodents, 1080-treated^{2/} wheat was distributed in the fall and spring on each area. The entire acreage in all three clearcuts was also seedspotted as part of a regular regeneration program, thereby minimizing chances for concentrated feeding on study plots by birds or surviving rodents.

Methods

In the first study, two plots were established at Lost Creek and on Red Blanket Mountain. Each plot consisted of 100 seedspots on about one-fourth acre. Prior to seeding, locations for seedspots were selected, scarified with a hand rake to expose at least 1 square foot of mineral soil, and marked with numbered wooden stakes. Then half of the spots were randomly selected for protection by conical screens constructed of 3/8-inch mesh hardware cloth (fig. 1).

The spots were seeded in October of 1964 with untreated seed of nearby sources. At Lost Creek, five western white pine and 10 noble fir seeds were sown over each prepared spot and covered with approximately one-half inch of mineral soil; at Red Blanket, five white pine and 10 Shasta red fir seeds were placed in each spot and similarly covered.

^{1/} Endrin is the generic name accepted by the Entomological Society of America for the insecticide 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethanonaphthalene. It is somewhat effective in protecting coniferous seeds from destruction by some rodents.

^{2/} Sodium fluoroacetate.

Table 1.--Description of clearcuts where study plots were located

Characteristic	Lost Creek	Red Blanket Mountain	Lusby Cabin
Location	Mount Adams Ranger District, Gifford Pinchot National Forest	Prospect Ranger District, Rogue River National Forest	Prospect Ranger District, Rogue River National Forest
Original forest type	Western hemlock—Douglas-fir—Pacific silver fir	Shasta red fir—mountain hemlock	Douglas-fir—grand fir
Elevation	3,500 feet	6,000 feet	4,500 feet
Aspect and slope	W., 5 percent	SE., 15 percent	W., 15 percent
Size of clear-cut	65 acres	35 acres	35 acres
Logged	In 1963	In 1964	In 1959
Slash disposal	Broadcast burned, fall 1963	Piled, not burned	Piled, not burned
Tractor scarification	Fall 1964	Fall 1964	Fall 1964
Baiting	2.8 pounds of 1080 ^{1/} wheat per acre; 40 to 50 grains in protected spots at 20-foot intervals during September. Additional spot baiting in May	1.6 pounds of 1080 ^{1/} wheat per acre spotted in protected spots. Additional spot baiting in May	1.6 pounds of 1080 ^{1/} wheat per acre spotted in protected spots. Additional spot baiting in May
Seeding	Entire unit seed-spotted with 10 to 15 seeds of white pine or Douglas-fir in alternate spots in fall 1964. Spots at 10- by 10-foot spacing	Entire unit seed-spotted with 12 Shasta red fir seeds per spot at 6- by 6-foot spacing	Entire unit seed-spotted with 12 Douglas-fir seeds per spot at 6- by 6-foot spacing

^{1/} Sodium fluoroacetate.

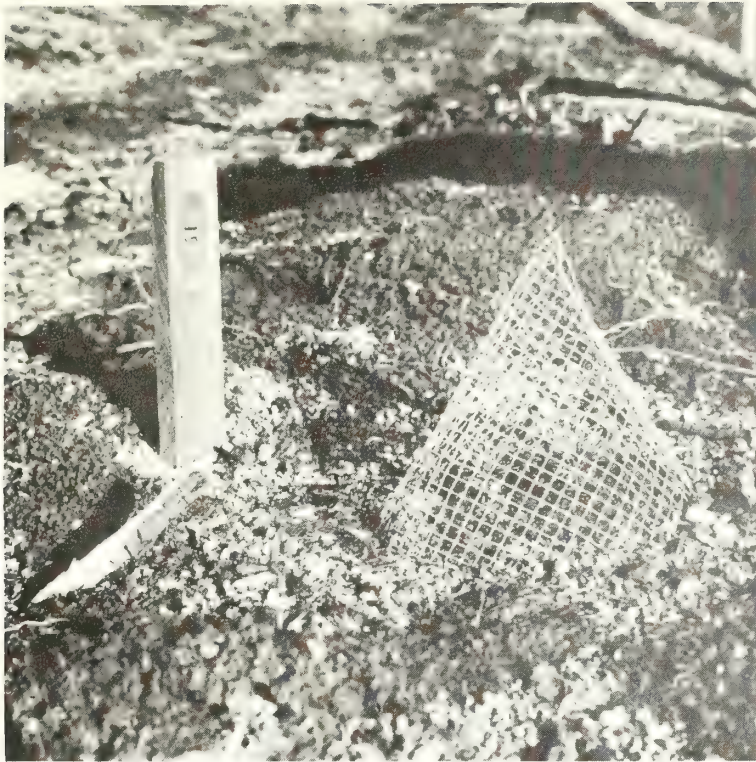


Figure 1.--*Conical screen in place over a seedspot.*

Unequal numbers of white pine and true fir seeds were planted to compensate for differences in percentage of filled seed. Field tests of 200 seeds from each lot, made during the first season of the study, provided these germination results:

<u>Source and species</u>	<u>Germination</u> (Percent)
Lost Creek:	
Western white pine	35.0
Noble fir	38.5
Red Blanket Mountain:	
Western white pine	59.5
Shasta red fir	28.5

However, over half of the Lost Creek and about one-fifth of the Red Blanket western white pine seed in the seedspots did not germinate until the second spring. Consequently, a more realistic germination percent would be 70 and 75 percent, respectively, for the Lost Creek and Red Blanket white pine seed.

The Lost Creek plot was examined six times and the Red Blanket plot five times during the 1965 growing season. Both were checked twice in 1966; the terminal examination was made in late fall. At each examination all seedlings on each seedspot were recorded as live or dead. Cause of mortality was recorded whenever identifiable with reasonable certainty.

Concurrently, the second seedspotting study, including endrin-treated and untreated Shasta red fir and Douglas-fir of local origin, was established on the Prospect Ranger District. The Shasta red fir installation was sown on the same Red Blanket Mountain clearcut used in the first study, and the Douglas-fir on the clearcut at Lusby Cabin. Loss of untreated seed, mortality of germinants, and seedling stocking were compared on (1) unscreened seedspots, (2) unscreened spots shaded on the south by an 8- by 10-inch square of fine mesh screen, and (3) screened spots completely protected by a screen cage. Similar observations were made on unprotected spots seeded with endrin-treated seed of the same species and sources. Fifty replications of these sets of four treatments were installed for each species. Each spot received 12 seeds which were covered with about one-fourth inch of mineral soil. This study was terminated at the end of the first growing season.

Results

White Pine and True Fir Seedspotting Study

After two growing seasons, stocking in screened seedspots was greatly superior to that in unscreened spots (table 2). Nearly twice as many seedlings germinated in screened spots, and survival percentage was significantly greater. As a result, stocking of 2-year-old seedlings in screened seedspots was about twice as much as in unscreened spots at Lost Creek, and over 10 times as much at Red Blanket.

White pine proved more successful than either true fir. Tree percent--percent of viable seed yielding seedlings at the end of the second growing season--was consistently higher for the pine:

	<u>Screened spots</u> (Percent)	<u>Unscreened spots</u> (Percent)
Lost Creek:		
Western white pine	59	18
Noble fir	14	5
Red Blanket Mountain:		
Western white pine	28	3
Shasta red fir	22	1

This is primarily because of the superior survival percentage for western white pine germinants, especially at Lost Creek (table 2).

Table 2.--Germination, survival, and stocking of western white pine and true firs in screened and unscreened seedspots, first study; data as of October 1966

Area and treatment	Germinants						2-year-old seedlings						Germinants surviving		
	Spots stocked with--			Seedlings present			Spots stocked with--			Seedlings present					
	Pine	Fir	Either	Pine	Fir	Total	Pine	Fir	Either	Pine	Fir	Total	Pine	Fir	Total
	----- Percent -----						----- Number -----						----- Percent -----		
Lost Creek:															
Screened	86	94	98	118	157	272	84	36	84	103	28	131	87	18	48
Unscreened	48	88	92	45	107	148	42	20	48	32	10	42	71	9	25
Red Blanket Mountain:															
Screened	82	80	94	107	87	191	52	36	62	53	32	85	50	37	44
Unscreened	54	36	64	64	32	93	6	2	6	6	1	7	11	3	8

The greatest single cause of seedling mortality was damping-off, although most of this was confined to true fir germinants (table 3). Damping-off caused 63 percent of all noble fir mortality and 29 percent of the Shasta red fir mortality. It killed few western white pine germinants. A part of these differences in damping-off of true fir and white pine germinants may be related to time of germination. True firs germinated much earlier at both locations. On May 18, 1965, 96 percent of the noble fir seedlings at Lost Creek had germinated, and 56 percent of these were dead from damping-off. Shasta red fir germination was 57 percent complete on June 8, and 21 percent of these germinants had damped-off. Western white pine seed did not germinate in quantity at either location until mid-June; in fact, 53 percent of the white pine germinants at Lost Creek and 20 percent at Red Blanket did not appear until the second summer.

Taken together, the categories of stem-clipped and missing seedlings (most of which were believed removed by animals, possibly including rodents, birds, slugs, shrews, and insects) accounted for 33 percent of all mortality (table 3). They were the most important categories of mortality for western white pine germinants at both locations. Clipping damage was not differentiated by causative agent, but agents other than rodents and birds were responsible since seedlings were clipped and removed from both screened and unscreened seedspots. If such damage within screens is ascribed primarily to insects and that outside primarily to rodents, then insects and rodents destroyed or damaged comparable numbers of germinants:

Seedlings clipped or missing
(Percent)

Red Blanket Mountain:

Screened spots	53
Unscreened spots	92

Lost Creek:

Screened spots	13
Unscreened spots	40

Other causes of mortality were relatively unimportant. Very little mortality occurred during the first winter or during the second growing season (table 3).

Douglas-Fir and Shasta Red Fir Seedspotting Study

Screening of seedspots also produced superior results in the second study (table 4). Screened seedspots contained many more germinants, had higher seedling survival, and had high stocking. In all comparisons, differences between screened and unscreened seedspots were highly significant. There were no significant differences between the

Table 3.--Amount and causes of seedling mortality by species and season, screened and unscreened seedspots, first study; data as of October 1966

Item	Lost Creek					Red Blanket Mountain				
	Screened spots		Unscreened spots			Screened spots		Unscreened spots		
	White pine	Noble fir	White pine	Noble fir	Total	White pine	Shasta fir	White pine	Shasta fir	Total
Total germinants	118	157	45	107	427	107	87	67	32	293
----- Number -----										
----- Percent -----										
Mortality by cause:										
First season: 2/										
Damping-off	3	61	2	43	34	0	26	3	6	9
Stem clipped	0	4	0	15	5	20	7	24	56	21
Missing	5	12	18	14	10	19	14	54	28	26
Heat	1	1	7	7	3	0	6	3	3	3
Drought	2	1	2	4	2	5	5	0	0	3
Unknown	1	1	0	0	1	0	0	0	0	0
Total	12	79	29	83	56	43	57	84	94	62
Overwinter:										
Missing	0	(3/)	0	5	1	1	1	0	0	1
Clipped	0	0	0	0	0	3	0	0	0	1
Unknown	1	1	0	0	1	0	0	0	3	(2/)
Total	1	1	0	5	2	4	1	0	3	2
Second season:										
Missing	0	1	0	3	1	2	5	3	0	3
Drought	0	0	0	0	0	2	0	0	0	1
Total	0	1	0	3	1	4	5	3	0	4
Total mortality	13	81	29	91	59	51	63	87	97	68
Seedlings damaged by clipping	2	1	5	7	4	16	17	4	6	13

1/ Individual percentages may not total due to rounding.

2/ Including mortality of white pine germinants appearing between June and November of the second season.

3/ Less than 0.5 percent.

Table 4. --Germination, survival, and stocking of Shasta red fir and Douglas-fir
on seedspots, second study; data as of October 1966

Item	Screened seedspots	Unscreened seedspots		
		Shaded, untreated seed	Unshaded	
			Treated seed ^{1/}	Untreated seed
Shasta red fir:				
Spots stocked.....	77	17	10	10
Germinants per spot.....	4.62	2.54	1.77	2.56
Established seedlings				
per spot.....	3.40	.27	.12	.15
Germinants surviving.....	74	11	7	6
Douglas-fir:				
Spots stocked.....	90	45	39	27
Germinants per spot.....	6.02	2.37	2.10	1.35
Established seedlings				
per spot.....	4.12	.96	.80	.47
Germinants surviving.....	68	40	38	35

^{1/} Endrin-treated.

shaded, unscreened seedspots and unshaded, unscreened spots seeded with either treated or untreated seed. Results were similar for both Douglas-fir and Shasta red fir.

Discussion

If 35- to 50-percent seedspot stocking is considered satisfactory, screened seedspots can be considered an unqualified success in both studies. Screened seedspots yielded better results by reducing seed and germinant losses to animals. About twice as many seedlings germinated in screened spots (tables 2 and 4), indicating that prior to germination half of the viable seed in unscreened spots was destroyed by rodents (and possibly shrews). Recovery of rodent-cracked seed hulls from many unscreened seedspots, but none from screened spots, confirmed cause of and differences in seed loss. Rodents also clipped and removed seedlings from unscreened seedspots, as previously pointed out.

Much greater seedling establishment on screened than on unscreened spots strongly suggests that rodent control activities were either inadequate or ineffective.

Western white pine was the most successful and true firs the least successful of the species sown in these two studies; Douglas-fir was intermediate. White pine failed only on unscreened spots at Red Blanket. In the first study, screened seedspots were only 36 percent stocked with true firs, a barely satisfactory showing (table 2). True fir stocking on unscreened spots was unsatisfactory in both studies, ranging from 2 to 20 percent (tables 2 and 4). True fir failures were not due to seed loss or inadequate germination but rather to very heavy seedling mortality (table 3), particularly from damping-off. Douglas-fir achieved 90-percent stocking of screened seedspots; unscreened spots were 27 to 45 percent stocked, but this was at the end of the first growing season and some additional seedling losses are to be expected.

Small seedling losses caused by heat and drought and major losses from insects and rodents, as recorded in the first study, were not surprising. Stein^{3/} observed damage of similar magnitude by these agents in seedspottings of sugar pine. The high proportion of noble fir germinants lost to damping-off fungi at Lost Creek was unexpected, although substantial mortality from damping-off has been recorded in other studies of seedspotting at high elevation.^{4/} Low overwinter mortality was also

^{3/} Stein, William I. A successful direct seeding of sugar pine. U.S. Forest Serv., Pacific Northwest Forest & Range Exp. Sta. Res. Pap. 25, 19 pp., illus. 1957.

^{4/} Ronco, Frank. Lessons from artificial regeneration studies in a cutover beetle-killed spruce stand in western Colorado. Rocky Mountain Forest & Range Exp. Sta. U.S. Forest Serv. Res. Note RM-90, 8 pp., illus. 1967.

somewhat unexpected, since seeding studies made by Jensen^{5/} near Lost Creek showed that frost heaving can be a major cause of mortality of one-season-old seedlings.

Statistical analysis of data from the second study showed that stocking of shaded seedspots or spots seeded with endrin-treated seed was not significantly better than stocking of unshaded spots seeded with untreated seed. Failure of shading to significantly improve seedling survival suggests that, as in the first study, heat and drought were not major causes of mortality. Data on number of germinants (table 4) indicate rodents destroyed substantial amounts of the unprotected Shasta red fir and Douglas-fir seed regardless of whether or not it was endrin-treated.

Conclusions

Poor establishment of seedlings in these small-scale seedspottings of western white pine, true firs, and Douglas-fir, except where screened--and not always then --indicates we need to know much more about seedspotting to make it a consistently dependable method of artificially regenerating upper-slope forests. Particularly, more information is needed about methods of protecting seed and seedlings from rodents and preventing seedling losses to insects and disease as Stein^{6/} has already pointed out.

^{5/} Jensen, Harold J. Regeneration studies in the High Cascades of southern Washington. Unpublished manuscript on file at the Pacific Northwest Forest & Range Exp. Sta., 13 pp. 1961.

^{6/} Stein, William I. Seedspotting - revival of an old technique. In Western Reforestation. West. Forest. & Conserv. Ass. Coord. Com. Proc. 1964: 18-20. 1965.

PNW-81

July 1968

THE LARGE ASPEN TORTRIX, *CHORISTONEURA CONFLICTANA* (WLKR.),
IN
INTERIOR ALASKA

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ABSTRACT

The large aspen tortrix caused extensive defoliation in interior Alaska during 1966 and 1967. Studies showed its life history to be similar to that reported from Canada. Overwintering larvae became active in early May and completed their development by early July. Natural mortality is discussed with emphasis on the effect of larval starvation on survival and egg production.

INTRODUCTION

An infestation of the large aspen tortrix, *Choristoneura conflictana* (Wlkr.), was discovered near Ester, Alaska, in June of 1966. Aerial observation in July showed various degrees of defoliation within aspen type over an area of about 5,000 square miles. The major infestation was north of the Richardson and Alaskan Highways, from Minto Flats east to George Lake (fig. 1). Defoliation was "patchy" within this area, varying from complete to no noticeable defoliation. Number of infested stands and degree of defoliation increased within this same general area during 1967--the entire area of noticeable defoliation about doubled in size. In addition, the insect was reported from various areas south of Glennallen and west toward Anchorage.

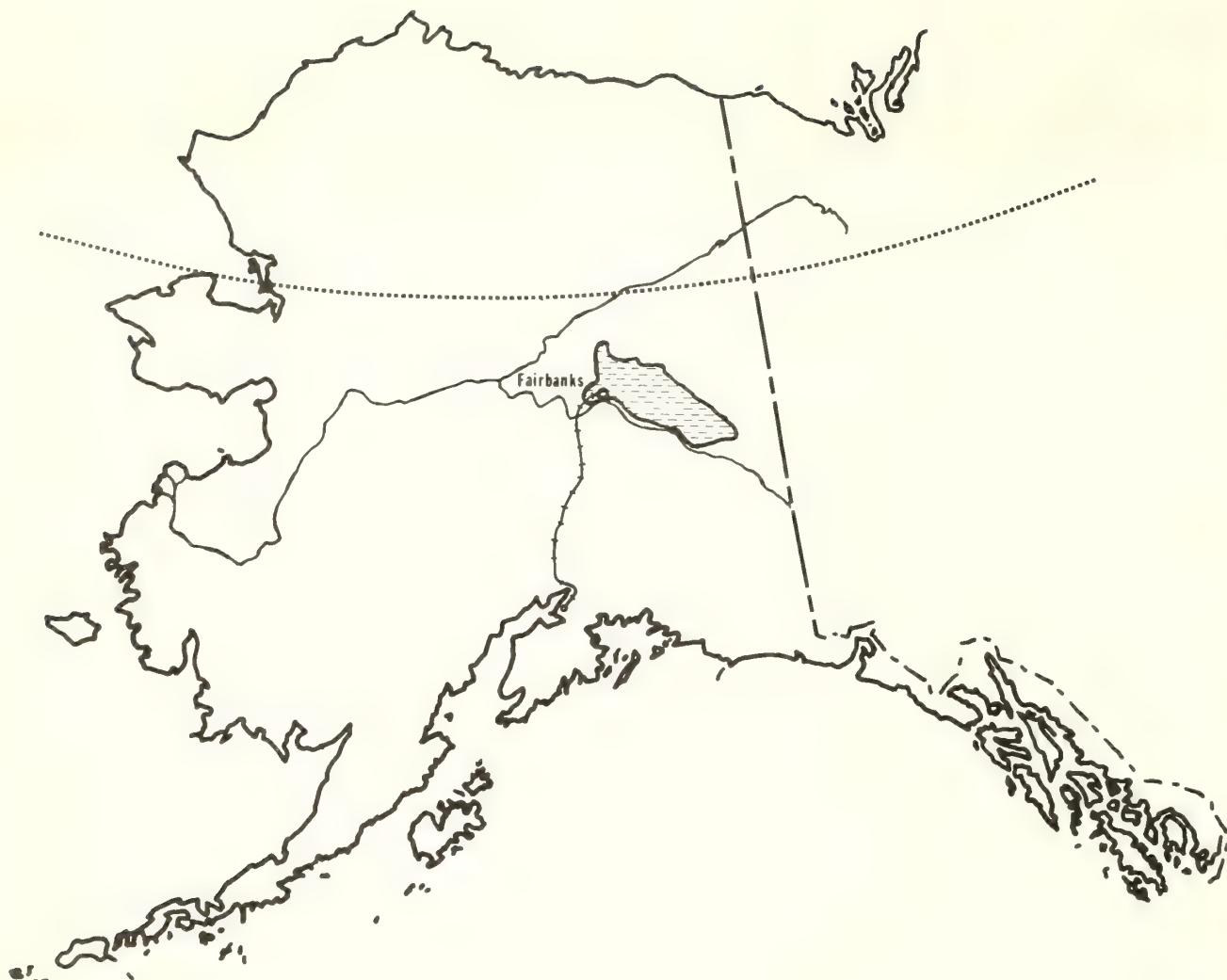


Figure 1.--Shaded portion shows area of heavy defoliation by *Choristoneura conflictana* in Alaska, 1966-67.

Adults reared from larvae during 1966 apparently represent the first record of this species from Alaska. Powell^{1/} places the northern distribution of this boreal species from New England across Canada to the Yukon Territory. It is likely that the species was present in Alaska in the past but was not collected. Radial growth data from 25-year-old aspen, birch, and spruce taken from the same site indicate the possibility of an insect defoliator on aspen during 1946-47. Lack of information on this species in interior Alaska prompted an investigation to determine its life history and habits.

MATERIALS AND METHODS

General observations were made of the large aspen tortrix following its discovery in 1966. Pupae were collected and kept in vials to record emergence, sex ratio, and parasitism. Two observation areas were established in the fall of 1966 in the vicinity of Fairbanks, Alaska. The Ester area is at an elevation of 750 feet; the Ester Dome area is at the 2,250-foot level. Weekly temperature records were kept throughout the year by the use of hygrothermographs. In addition, temperatures above and below snowline were taken weekly by use of thermistors attached to trees within the area.

Beginning in early May of 1967, branch samples were taken at weekly intervals from four trees within each observation area. The first 25 buds per branch and all growth from these buds were examined and all larvae counted and saved for future reference; this was similar to the sampling method used by Henson.^{2/} Complete destruction of the buds by the heavy larval population stopped the branch sampling.

Fifty larvae were collected at 2-day intervals and the head capsules measured by use of an ocular micrometer. The measurements were grouped into 0.02 mm. classes and plotted in the form of an accumulative histogram (fig. 2).

Pupae were collected from rolled leaves and placed in gel capsules for rearing. Emerging adults were sexed and disposed of at daily intervals; all parasites were saved. Egg masses were collected from each plot during the middle of the oviposition period. Additional collections were made in an area of light defoliation to make egg mass size

^{1/} Powell, J. A. Biological and taxonomic studies on tortricine moths, with reference to the species in California. Univ. Calif. Pub. Entomol., vol. 32, 317 pp. Berkeley and Los Angeles: Univ. Calif. Press. 1964.

^{2/} Henson, W. R. A sampling system for poplar insects. Can. J. Zool. 32:421-33. 1954.

comparisons. Egg masses were fixed in Kahle's fluid, transferred to a 70-percent ethanol solution, and later photographed to facilitate counting.

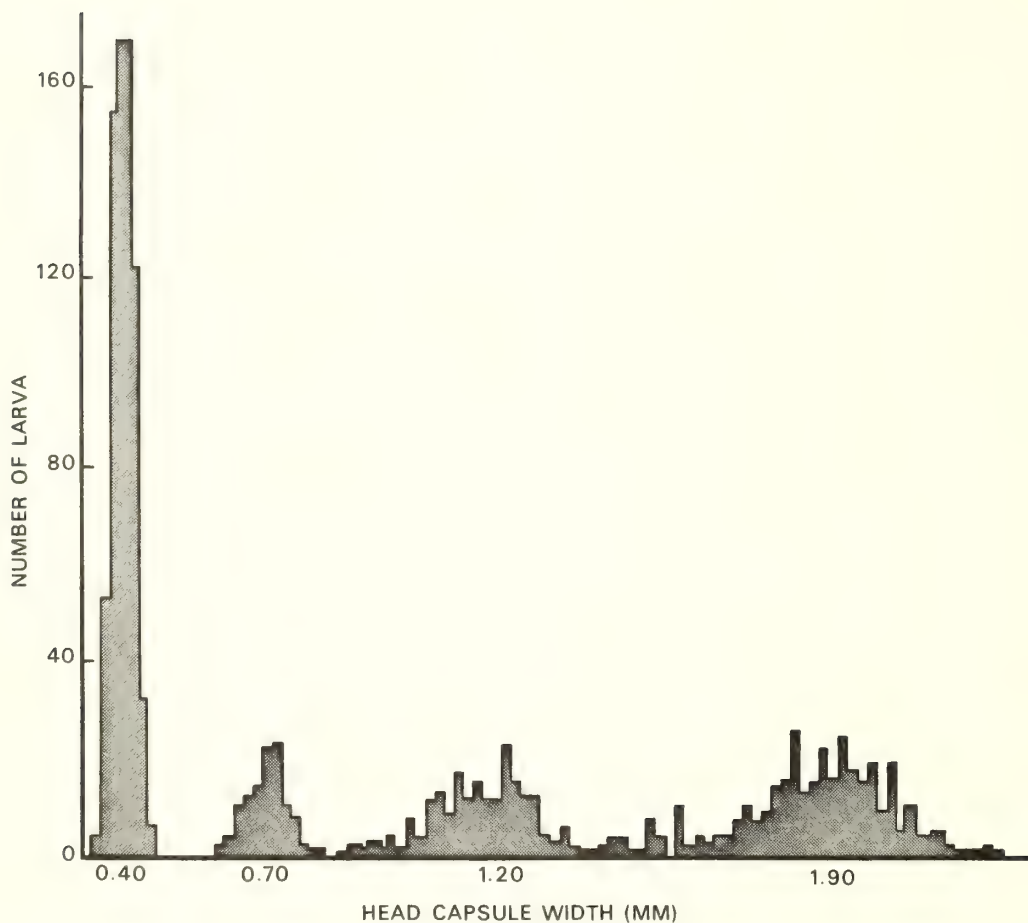


Figure 2.--Histogram of the head-capsule widths of *Choristoneura conflictana* larvae. The first instar has been omitted.

LIFE HISTORY

The life history of the large aspen tortrix in Alaska's interior is similar to that reported in northern Manitoba and Saskatchewan, Canada, by Prentice.^{3/} The seasonal development (fig. 3) is slightly different due to local climatic patterns.

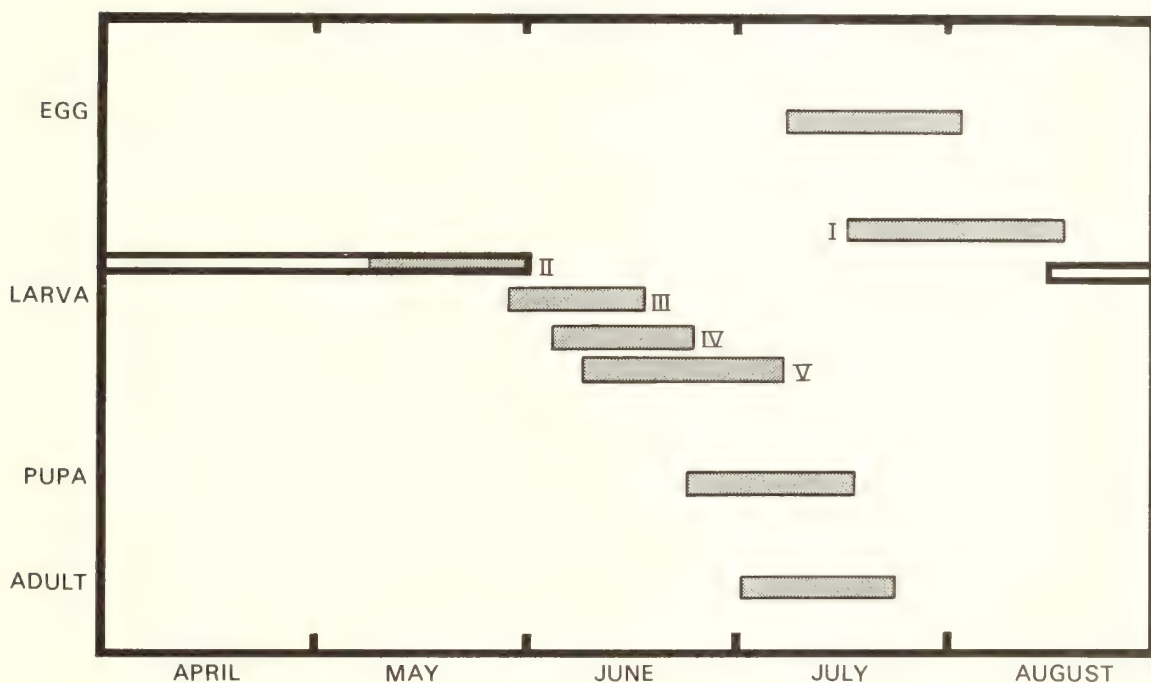


Figure 3.--Generalized seasonal development of *Choristoneura conflictana* in interior Alaska. The blank portion of the second instar represents the overwintering stage.

The insects overwinter as second-instar larvae within hibernacula spun in protected places. Overwintering sites may be found in moss and bark crevices at the base of trees, dead bark on twigs on the ground, and dead bark on twigs attached to trees. Qualitative observations during the spring of 1967 indicated that bark scales on twigs above the ground were favored as overwintering sites. These observations were

^{3/} Prentice, R. M. The life history and some aspects of the ecology of the large aspen tortrix, *Choristoneura conflictana* (Wlkr.) (N. Comb.) (Lepidoptera: Tortricidae). Can. Entomol. 87:461-473. 1955.

made during a period of population increase. Wickman^{4/} reported this same preference for hibernacula niches in California. This apparent choice of sites may be the result of population levels, stand characteristics, and/or the result of sampling methods.

There are five larval instars. The first instar is not shown in figure 2 because collecting did not start until the second instar was reached. Laboratory reared larvae underwent five instars; however, two individuals had six--probably a response to food or the microclimate inside the rearing containers.

The small larvae begin to migrate up the stems of aspen on warm days in early May. At this stage, they have yellowish bodies and black heads. In 1967, the first larvae were active on May 8 and May 17 at Ester and Ester Dome, respectively. Secondary hibernacula (fig. 4) were often constructed at the base of buds, possibly as a reaction to adverse temperatures. At this time of year, the temperatures during the day reached a maximum of 15° C. and the night temperatures went down to 0° C. or near it. The larvae mine into the buds and destroy the young tissue. Up to seven larvae per bud were found in the early stages of bud expansion. Complete defoliation may result before the buds have broken. The later stage larvae feed more openly; at this time, they are gray-green to black in body color with dark head capsules.



Figure 4.--Aspen buds with a secondary hibernaculum constructed between them. Two entrance holes covered by silk can be seen in the larger bud on the left.

^{4/} Wickman, B. E. The large aspen tortrix, *Choristoneura conflictana* in California (Lepidoptera: Tortricidae). J. Econ. Entomol. 56:494-496. 1963.

The pupae (fig. 5) are found within rolled leaves on the tree. Understory plants are often used as pupation sites in heavily defoliated stands. Adults are active from late June through early July.



Figure 5.--Pupa of *Choristoneura conflictana* that has been extracted from a rolled leaf.

The moths (fig. 6) are dull in color; the forewings are grayish with brownish markings. The females are fairly sluggish moths and appear to stay in the area of emergence. The sex ratio is approximately 1:1. The greenish egg masses are deposited primarily on the upper surface of the leaves; however, they can be found on the leaf undersides,



Figure 6.--Adult female of *Choristoneura conflictana*.

trunks, and on other vegetation. The number of eggs per mass in a nonstarved population ranged from 63 to 413. The eggs hatch by the last of July; first-instar larvae are active until mid-August. They feed gregariously within rolled leaves, skeletonizing the upper and lower surfaces. Leaves that had been rolled for pupation are a favorite feeding site for young larvae. The larvae migrate to protected areas, spin the hibernacula, molt to the second instar, and enter the overwintering stage.

NATURAL MORTALITY

Starvation was probably the most important mortality factor during 1967; this was not the case in 1966. Many areas were completely denuded before the buds had fully expanded. The lack of foliage caused the larvae to wander in search of acceptable food. Extensive webbing covered the grasses and herbaceous understory plants. Spruce trees were completely "tented over" by these webs, but not fed upon to any great extent. Many third- and fourth-instar larvae died, apparently from lack of acceptable food.

The number of eggs per mass was greatly reduced during 1967 as compared with 1966 at Ester and Ester Dome (table 1). Both study areas were completely defoliated 2 years in succession. The reduction of eggs per mass appears to be a direct result of larval starvation. In contrast, a nearby area (Chena) suffered heavy defoliation in 1967 only; the number of eggs per mass was comparable to the number produced in 1966 in the other two areas. Experiments are being conducted to determine the effect of food quantity and quality on fecundity.

Table 1.--Eggs per mass of *Choristoneura confliotana*
near Fairbanks, Alaska

Area	1966			1967		
	Number masses	Mean number eggs	Standard deviation	Number masses	Mean number eggs	Standard deviation
Ester	25	245.84	75.050	25	129.44	76.646
Ester Dome	100	224.28	62.717	25	124.00	56.365
Chena	--	--	--	25	241.32	97.942

Several parasites caused reduction in aspen tortrix populations in 1966 and 1967. The egg parasite, *Trichogramma minutum* Riley, attacked 90 percent of the egg masses; 1 to 33 percent of the eggs in each mass were parasitized (fig. 7). The tachinid, *Omotoma fumiferanae* (Toth.), destroyed between 34 and 61 percent of the population in 1966, based on four separate collections. General observations in 1967 indicated reduced effectiveness of this parasite. Only a few hymenopterous parasites were reared from pupae during 1966; *Phaeogenes* sp., probably *hariolus* (Cress.), was the most common.

In 1967, a large number of hymenopterous adults were reared from pupae collected in the two sample areas. Total parasitism by about six species was 22 percent at Ester and 5 percent at Ester Dome. The adults are being identified. The impact of the various species upon the host population has not been determined.

Low-temperature effects appeared to be minimal in the study areas. The overwintering survival of the 1966 population was excellent despite larvae being exposed to periods of below -25° C. which held for as much as 72 hours. The temperature was in the -40 's but not recorded due to ink flow failure during one period of about 3 days. Temperatures beneath the snow at the soil line were 10° to 25° C. warmer than air temperatures during periods of cold extremes. However, twig samples collected in February above snowline showed successful emergence of second-instar larvae.

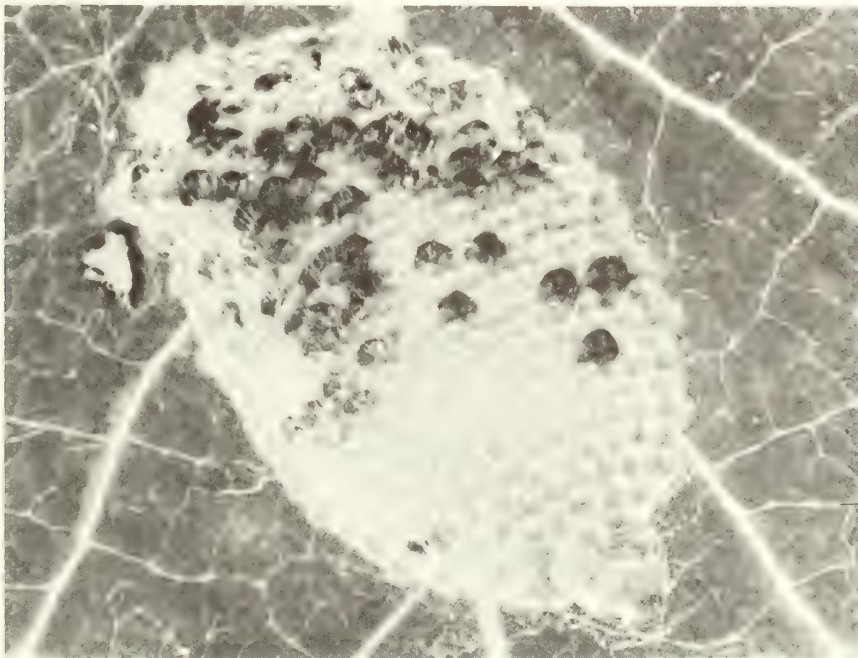


Figure 7.--Egg mass of *Choristoneura conflictana*. The black eggs are parasitized by *Trichogramma minutum* and the white "eggs" are empty chorions following eclosion.

DISCUSSION

The large aspen tortrix causes periodic outbreaks elsewhere in its range. Records of past infestations are not available for Alaska. It is probable that the insect has been present and is cyclic.

The factors responsible for population fluctuations in Alaska are not known. A number of parasites were reared; the effectiveness of these parasites was not determined. Starvation apparently is important in the rapid decline of large populations. In 1967, larvae in the areas observed were starving in the third and fourth instar. Heavy mortality occurred at this time. The reduction in number of eggs per mass appears to be the direct result of larval starvation. The scarcity of egg masses indicates low survival to the adult stage.

In interior Alaska, it appears that large aspen tortrix populations will probably collapse following 2 or 3 consecutive years of complete defoliation. Those stands severely defoliated for only one season will probably support a large population for another year.

PNW-82

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CAN THINNING SLASH CAUSE A NITROGEN DEFICIENCY
IN PUMICE SOILS OF CENTRAL OREGON?

by

P. H. Cochran, *Soil Scientist*

ABSTRACT

Decomposition of thinning slash deposited on the soil surface should have no direct adverse effect on the soil nitrogen available to higher plants in the pumice soil region. Decomposition of roots of cut trees would immobilize nitrogen in the soil immediately adjacent to the root during the decomposition period, which appears to be short for the smaller roots. However, these dead roots no longer compete for soil nitrogen in unexploited soil zones. Thus, nitrogen available for individual trees may be increased by thinning. If chipped slash is mechanically incorporated into the soil, a temporary nitrogen deficiency is likely, particularly in nonpumice soils. This deficiency can be prevented by fertilization.

INTRODUCTION

The question posed by the title deserves comment at this time for several related reasons. Thinning stands to wide spacings, in studies now underway in central Oregon, have resulted in large increases in individual lodgepole and ponderosa pine tree growth. In some of these studies, the slash was removed after thinning. In contrast, slash is not removed in the thinning operations on National Forest lands in central Oregon. Although comparative data have not



been collected, some foresters feel that the thinning on their districts has not resulted in the growth increases which the thinning studies indicate are possible. Nitrogen deficiencies during slash decomposition have been suggested as a reason for this possible discrepancy.

The incorporation of organic material with a wide C:N ratio does result in decreased nitrogen availability to higher plants during the decomposition period if a large portion of the carbon is readily available to the microbial population. The addition of the readily available carbon provides an energy source for the microbial population. If other environmental factors are favorable, the numbers of microbes increase and their activity becomes so intense that much of the soil nitrogen which would otherwise be available to higher plants is utilized in the formation of microbial protoplasm. As the added carbon is microbially attacked, some is given off as CO₂ and the C:N ratio gradually narrows. As the C:N ratio narrows, the microbial activity subsides and the nitrogen released for higher plants increases to its former level. The effects of adding the organic material should be expected to last longer in the pumice soil region; there, low soil temperatures and periodically dry surface soil horizons retard the decomposition process. When the meadows in the region were homesteaded in the 1920's and 1930's, rye was a principal crop. In order for a rye crop to be grown, the land had to be fallow for at least 1 year after plowing.^{1/} Therefore, nitrogen was probably not available for the growth of higher plants immediately after the native meadow vegetation was turned under. A 1-year fallow period was necessary before the C:N ratio of the added residue narrowed and the microbial activity slackened, allowing the release of N for uptake by higher plants.

THE EFFECT OF C:N RATIOS OF INCORPORATED RESIDUES ON NITROGEN IMMOBILIZATION AND MINERALIZATION

Immobilization is a mechanism by which micro-organisms reduce the quantity of nutrients available to plants in the soil; nitrogen mineralization is the conversion of organic nitrogen to the inorganic state (1).^{2/}

In an undisturbed soil, the microbial activity in a given season and the C:N ratio are fairly stable. As plant, animal, and microbial residues are gradually added, microbes attack and decompose all but a small amount of very resistant material (primarily lignin and some protein) which is added to the humus complex. The humus complex, in turn, is continually being attacked by the microbial population, and

^{1/} Personal communication, Archie Deadmond, Silver Lake, Oregon.

^{2/} Italic numbers in parentheses refer to Literature Cited, p. 11.

the amount of nitrogen, carbon, and other nutrients added through decomposition of fresh animal, plant, and microbial residue balances the amount of these materials released from the humus by slow and continual microbial decomposition. All of the carbon and nitrogen in the residue either passes through the tissue of the living microbes (after which some nitrogen may be mineralized or some carbon released as CO_2) or these elements are added to the humus complex to be eventually released by decomposition. The overall results of these processes are that the additions and losses of C, N, and other nutrients are nearly in balance and that the C:P, C:K, and C:S ratios, as well as the C:N ratio, are nearly constant.

The C:N ratio of a soil is a weighted average of the C:N ratio of the living microbial tissue (4:1 to 9:1) and the other organic material, primarily humus, which has a wider C:N ratio (1). The C:N ratios of most arable soils vary from 8:1 to 15:1 (4).

Since C:N ratios for given soils are a result of a dynamic equilibrium, as decomposition of added organic material with a wide C:N ratio occurs, the C:N ratio of the added residue is gradually narrowed. After decomposition, the original C:N ratio of the soil is maintained. During decomposition, the microbial population assimilates a portion of the added carbon for generation of new protoplasm, and there is also a concomitant uptake of N and other nutrients. The rest of the carbon is liberated as CO_2 or is added in organic form to the humus complex to be more slowly decomposed later.

The above discussion can be illustrated by the following hypothetical problem:

Suppose that 2,000 pounds of wheat straw (0.5 percent N and 40 percent C) are added to a soil having a C:N ratio of 15:1. This carbon is readily available, and it is reasonable to assume that the microbial population will release 66 percent of the added carbon as CO_2 , and that the other 34 percent will be added to the organic carbon already in the soil (1, p. 40). In this example, 272 pounds of carbon (2,000 pounds $\times$ 0.40 $\times$ 0.34) will be added. In order for the microbial population to carry out the decomposition process and in order for the C:N ratio to remain stable, 18.1 pounds of nitrogen ($\text{N}:272 = 1.15$; $\text{N} = 18.1$) must be tied up either by the microbial population or with the slowly decomposable portions of the straw which are added to the humus without being passed through microbial tissue. The nitrogen content of the straw is only 10 pounds ($0.005 \times 2,000$), so an additional 8.1 pounds ($18.1 - 10$) must be supplied for the decomposition process. Therefore, during decomposition, the amount of nitrogen available for higher plant uptake will be reduced by 8.1 pounds. Similar calculations can be carried out to show that incorporation of a material with a narrow C:N ratio, such as alfalfa, would result in an increase in the amount of nitrogen available for higher plants.

THE EFFECT OF SLASH ON NITROGEN IMMOBILIZATION AND MINERALIZATION

When a stand is thinned and the slash is left on the ground, the microclimate is considerably modified. Briefly, soil temperatures under slash are cooler and undergo less variation than if slash is removed. Also, evaporation from slash-covered soils is less than from areas where slash is removed. The resulting effects on tree growth are impossible to assess. In a corn mulching study, conducted at various locations throughout the cornbelt, mulching decreased soil temperatures in the northern portion of the cornbelt and thus decreased corn growth there (6).

Data now available for pumice soils do allow some conclusions concerning the effect of slash on nitrogen immobilization and mineralization for the pumice region. The C:N ratio for the combined Al and AC horizons of a Lapine pumice soil is a surprisingly high 22.8:1.^{3/} If we assume bulk densities of 0.7 g./cm.³ and 0.6 g./cm.³ and horizon depths of 0-2 inches and 2-10 inches for the Al and AC horizons, respectively, and use the N content data given by Dyrness,^{4/} the value of 824 pounds of nitrogen per acre can be calculated for a pumice soil.

For woody plants in general, the C:N ratios for wood, bark, and foliage are about 500:1 or more, 300:1, and 50:1 to 25:1, respectively.^{5/} In the heaviest thinning in central Oregon, more than 58,500 pounds of slash per acre were left on the ground.^{6/} Obviously, if all of this material were ground up and incorporated into the soil profile, serious nitrogen deficiencies would result if all of the incorporated carbon was readily utilized by the microbial population. However, coniferous wood, bark, and sawdust contain 60 to 70 percent of inherently resistant lignocellulose. This substance decomposes so slowly that resistance to attack rather than available nitrogen controls its rate of decomposition (3). Further, this material is not ground up, is not incorporated into the soil profile immediately, and, from some indications, a large part is never incorporated.

^{3/} Dyrness, Christen Theodore. Soil-vegetation relationships within the ponderosa pine type in the central Oregon pumice region. 217 pp. 1960. (Unpublished Ph. D. thesis, on file at Oreg. State Univ., Corvallis.

^{4/} See footnote 3.

^{5/} Leaf, Albert L. Wood waste: a valuable soil amendment. 8 pp. 1962. (Unpublished report on file at Silvicult. Dep., State Univ. Coll. Forest. at Syracuse.)

^{6/} This thinning was carried out in 1965 in connection with a levels-of-growing-stock study. The weight was estimated by the method given by Fahnestock (5)

Fahnestock (5) found that the fine twigs and all the larger branches of pine slash were still intact at the end of a 3-year study period. He also found that foliage fell gradually from the slash of ponderosa and lodgepole pine, and that, 3 years after cutting, supported foliage still was an important fuel component. Observations of thinnings conducted on the Deschutes National Forest show that limbs of 9-year-old ponderosa pine slash in the Green Mountain area are still intact and appear no more decomposed than comparable dead limbs on living trees. Needles were off the slash, but many were still on top of the ground unincorporated into the soil profile. Other observations of thinnings in central Oregon indicate that needles stay on the slash for at least 3 years but are off the slash and on the ground at the end of the 5th or 6th year and that slash limbs are still above ground at the end of 9 years. Therefore, in the first decade after thinning, only a portion of the pine needles become incorporated into the soil profile. The question now becomes: What is the effect of needle addition on nitrogen availability to higher plants?

In the heavy levels-of-growing-stock thinning, we estimate, by use of Fahnestock's (5) data, that there are 12,400 pounds of foliage included in the 58,500 pounds of slash per acre. The nitrogen content of ponderosa pine foliage has been shown to vary from 0.51 percent for 350-year-old stands to 0.79 percent for 100-year-old stands (9). The carbon content of this material is about 40 percent.^{7/} If we used a conservative estimate of 0.65 percent N for the foliar content of the levels-of-growing-stock study slash, the C:N ratio of the foliage would be approximately 62:1. If we assume that all 12,400 pounds of foliage were incorporated into a profile where the C:N ratio of the soil is 22.8:1, the amount of N mineralized or immobilized during the decomposition can be calculated by use of the valid assumption (1, p. 40) that 66 percent of the added carbon is given off as CO₂. These calculations follow:

- (1) Amount of carbon added in the foliage:
 $12,400 \times 0.40 = 4,960$ pounds per acre
- (2) Amount of carbon retained after decomposition of foliage:
 $4,960 \times (1.00 - 0.66) = 1,686$ pounds per acre
- (3) Amount of nitrogen which must be used during decomposition:
 $1:22.8 = N:1,686$
 $N = 74$ pounds per acre

^{7/} C. T. Youngberg, professor of forest soils, Oregon State University, personal communication.

- (4) Amount of nitrogen added in the foliage:

$$12,400 \times 0.0065 = 80.6 \text{ pounds per acre}$$

- (5) Since the amount of nitrogen added in the foliage is greater than the amount necessary for decomposition, the amount of N mineralized or made available to higher plants is:

$$80.6 - 74.0 = 6.6 \text{ pounds per acre}$$

From observations of slash left by thinning of ponderosa pine in the Deschutes National Forest since 1958 and from the above calculations, the following conclusion has been made. If there is a difference in growth between the thinning studies where slash has been removed and in other thinning operations where slash has not been removed, it is not due to nitrogen immobilization resulting from slash decomposition in the pumice region. Interestingly, in agreement with the above calculations, Stone and Will (8) concluded that some of the nitrogen in the litter and slash from Monterey pine becomes available for use of pine seedlings in some areas of New Zealand.

What would be the effect if this amount of slash were added to a soil with a narrower C:N ratio of 10:1? The amount of nitrogen which would be necessarily tied up during the decomposition period would be:

$$1:10 = N:1,686$$

$$N = 169 \text{ pounds per acre}$$

If all of the foliage were immediately incorporated into this soil, the amount of nitrogen in the added foliage would not be great enough to allow for decomposition without the immobilization of 88.4 pounds of nitrogen per acre (169 pounds N per acre - 80.6 pounds N per acre = 88.4 pounds N per acre). However, the period of immobilization would be brief because the high soil nitrogen content would permit a rapid buildup of an active microbial population, which would soon decompose the foliage. After a brief decomposition period, there would be an increase of 88.4 pounds of nitrogen per acre in the soil minus the amount of nitrogen which had escaped from the profile by leaching or volatilization during the decomposition period. In short, there would be some immobilization during a brief decomposition period; then an increase in nitrogen for the growth of higher plants is likely.

In the forested stand, the needles are slowly incorporated into the soil profile by small macroanimals such as small mammals, insects, slugs, snails, mites, and earthworms (4). Thus, the decomposition period is lengthened, and portions of the added foliage are decomposed before other portions are incorporated into the soil profile. Therefore, the amount of nitrogen immobilized at any given time would be small in comparison with the total nitrogen in the soil. Detailed information about the carbon and nitrogen contents of the soils and

of the foliage and about the length of the decomposition period is necessary before a specific statement can be made about the nitrogen immobilized in any given thinned stand.

THE EFFECT OF ROOTS OF CUT TREES ON NITROGEN IMMOBILIZATION

The soil environment of a zone 5 to 20 mm. from the root surface is unique. Sloughed-off root cells provide material for microbial development, and the active root exudes substances which usually enhance microbial activity (7). The carbon dioxide and oxygen concentrations differ considerably from those in the soil some distance from the root. This zone, which is under the influence of the plant roots, is called the rhizosphere (1, 7).

The microbial activity within the rhizosphere is maintained at a more constant and intense level than in the other soil regions (1, 7), and the number of organisms may be 10 to 100 times as great as elsewhere in the soil (4). The individual organisms are also much more active biochemically than organisms from other parts of the soil (1, p. 446). Because of the competitive stress due to the large, active, fast-growing population, much of the nitrogen in the rhizosphere is immobilized at any given time, but the rate of turnover is rapid (1, p. 451).

When a root dies, an active microbial population is present, so the root immediately begins to decompose. Observations of thinned stands in the pumice soil region indicate that the largest roots of trees up to approximately 5 inches in d.b.h. decompose in about 5 years. Smaller roots decompose much faster. The decomposition of the root tissue occurs in much the same manner as decomposition of incorporated foliage. Carbon from the root tissue is utilized by the microbes, and a portion is released as CO_2 . The nitrogen is tied up by succeeding generations of microbes; these continually attack the roots until the supply of readily available carbon is exhausted and only the very slowly decomposable material is left. By then the activity of the microbial population has receded to a level comparable with its activity in other parts of the soil, and a portion of the nitrogen in the original rhizosphere becomes available for uptake by roots of other plants which invade the area.

The uptake of nitrogen and other nutrients occurs mostly through young, nonsuberized roots continually being produced when soil temperatures are above a certain critical level. These roots either move into unoccupied soil areas to take up nitrogen, primarily as NO_3^- or NH_4^+ , or these ions flow to the absorbing root surfaces in the soil solution. Since most of nitrogen in the rhizosphere of a living root is immobilized at any one time (1, p. 451), the death of this root

would not necessarily result in a decrease in nitrogen available to the remaining live roots. During the decomposition period of the dead roots, the nitrogen in the rhizosphere is completely tied up by the microbial population. However, the rhizosphere area of the dead root system continually shrinks as the roots decompose, and in addition, these dead roots are no longer extending into unoccupied soil to compete with the remaining live roots. As a result, the roots of trees left in a thinned stand may be able to take up more nitrogen than before the stand was thinned.

One test of this hypothesis would be to analyze the foliage of thinned and unthinned stands. To the author's knowledge, this has not been done for any western conifer. Boggess (2) studied the influence of thinning on the foliar nitrogen content of shortleaf pine in southern Illinois. He found significant increases in foliar nitrogen for trees on plots which had been thinned 2 to 3 years earlier than for those on unthinned plots. The increases in foliar nitrogen on the thinned plots were attributed to more rapid breakdown of litter caused by increased sunlight reaching the forest floor and to the availability of more nitrogen per tree when more than one-third of the basal area was removed.

THE EFFECT OF CHIPPED SLASH ON NITROGEN IMMOBILIZATION

Thinning slash along roadsides and in or near recreational areas is often chipped and left on the surface of the soil. As long as the material is left on the surface, it will have little or no direct effect on the availability of nitrogen to higher plants. No data are now available on the rate of incorporation and decomposition of this material. Observations on the Deschutes National Forest suggest that larger wood chips remain on the surface for several years. These large chips, like the larger log and limb material, are invaded by fungi and other organisms and may be decomposed primarily above ground.

In many potential recreational areas, it may become desirable to incorporate this chipped material into the soil by rototilling or by some other method and to establish an attractive vegetative cover. In this case, nitrogen deficiency for higher plants is possible, and applications of fertilizer nitrogen may be desirable.

As mentioned previously, if all the carbon in the incorporated slash was readily available for microbial utilization, the nitrogen deficiency would be serious. However, unlike foliage carbon and nitrogen, much of the nitrogen and carbon in bark and wood is not readily available. Conifer wood bark and sawdust are so resistant to attack that this resistance rather than available nitrogen controls

the rate of decomposition (3). According to Bollen,^{8/} ponderosa pine sawdust contains 50 percent carbon and 0.05 percent nitrogen, but 1 ton of this material contains only 50 to 100 pounds of available carbon and almost no nitrogen. Bollen has found that 3 to 5 pounds of elemental nitrogen for each ton of dry sawdust will suffice for initial decomposition. After the initial decomposition, the more resistant carbon will decompose more slowly, and succeeding generations of micro-organisms can reuse the same nitrogen. This prevents appreciable amounts of nitrogen from being immobilized by the microbial population at any one time. Greater nitrogen additions may function directly as a fertilizer, but such additions will not appreciably hasten decomposition of the sawdust (3).

Fahnestock's data (5) show that approximately 80 percent of ponderosa and lodgepole pine slash is composed of bark and wood. Using the results of Bollen, 4 pounds of nitrogen per ton of dry incorporated slash

(5 pounds per ton of sawdust x 0.80 = 4 pounds per ton of slash),

should prevent nitrogen deficiency for the higher plants during the decomposition of the wood and bark. Many of the chips are large and are therefore even less subject to rapid decomposition than sawdust, and a portion of the foliar nitrogen would become available in pumice soils. For these two reasons, 4 pounds of nitrogen per ton of dry incorporated slash should prevent temporary nitrogen starvation and should even allow some of the added nitrogen to act directly as a fertilizer.

In nonpumice soils, where incorporated foliar decomposition requires additional nitrogen, a rough rule of thumb can be used in calculating the amount of nitrogen which should be added with the incorporated chipped slash. This rule^{9/} states that the C:N ratio of incorporated foliage should be reduced to 30:1 by adding nitrogen to prevent a temporary nitrogen deficiency. The foliar C:N ratio is about 62:1. One ton of slash contains about 400 pounds of foliage (2,000 pounds x (1.00 - 0.80)). The foliar carbon content of this amount is 160 pounds (400 pounds x 0.40), and the foliar nitrogen content is 6.5 pounds (62:1 = 400 pounds:N pounds). The amount of nitrogen that must be added to reduce the foliar C:N ratio to 30:1 is calculated as follows:

^{8/} Bollen, W. B. Artificial manure and composts--proportions of nitrogen and other additions per ton of dry material. (Unpublished, undated report on file at Microbiology Department, Oregon State University.)

^{9/} See footnote 5.

(1) Amount of nitrogen necessary for the 30:1 ratio:

$$400:N = 30:1$$

$$N = 13.3 \text{ pounds}$$

(2) Amount of nitrogen which must be added to balance the readily available foliar carbon equals the amount needed minus the amount present in the foliage:

$$13.3 \text{ pounds} - 6.5 \text{ pounds} = 6.8 \text{ pounds}$$

For nonpumice soils, the total amount of nitrogen to add to prevent nitrogen immobilization due to incorporated chipped slash would equal:

1. the amount necessary to provide for utilization of the readily available carbon in the wood and bark (4 pounds N per dry ton;
2. plus the amount necessary for foliar decomposition (6.8 pounds N per ton) or 10.8 pounds of nitrogen per ton of dry slash.

SUMMARY

If differences in growth have occurred in thinning studies where slash has been removed and in other thinning operations where slash has not been removed, it is not due to nitrogen immobilization resulting from slash decomposition in the pumice soil region. In other soils, decomposition of aboveground slash may result in some small immobilization, but data are not available to confirm this.

The microbial population associated with decomposing roots of dead trees immobilize nitrogen in the soil zone immediately adjacent to the roots. The roots of the trees that are left have less competition for unexploited soil, and the amount of nitrogen available for individual trees may be increased by thinning. Foliar analysis data for thinned and unthinned stands must be collected so this phenomenon can be fully understood.

Chipped slash, if incorporated into the soil, could temporarily deprive plants of nitrogen, particularly in nonpumice soils. Calculations are presented to show the amount of nitrogen to add to prevent this temporary deficiency.

LITERATURE CITED

1. Alexander, Martin.
1961. Introduction to soil microbiology. 472 pp. New York: John Wiley and Sons.
2. Boggess, W. R.
1959. Foliar nitrogen content of shortleaf pine as influenced by thinning. Univ. Ill. Agr. Exp. Sta., Urbana. Forestry Note No. 80, 2 pp.
3. Bollen, Walter B.
1953. Mulches and soil conditioners--carbon and nitrogen in farm and forest products. Agr. & Food Chem. 1: 379-381.
4. Buckman, Harry O., and Brady, Nyle C.
1962. The nature and properties of soils. 567 pp. New York: The MacMillan Co.
5. Fahnestock, George R.
1960. Logging slash flammability. U.S.D.A. Forest Serv; Intermountain Forest & Range Exp. Sta. Res. Pap. 58, 67 pp.
6. Larson, W. E., Burrows, W. C., and Willis, W. O.
1960. Soil temperature, soil moisture, and corn growth as influenced by mulches of crop residues. 7th Int. Congr. Soil Sci. (Madison) I: 29, 629-637.
7. Parkinson, D.
1967. Soil micro-organisms and plant roots. Pp. 449-478. In Soil biology. Ed. by A. Burges and F. Raw London and New York: Acad. Press. 532 pp.
8. Stone, E. L., and Will, G. M.
1963. Nitrogen deficiency of second generation radiata pine in New Zealand. Pp. 117-139. In Forest-soil relationships in North America. Ed. by C. T. Youngberg. 532 pp. Oreg. State Univ. Press, Corvallis.
9. Tarrant, R. F., Isaac, L. A., and Chandler, R. F.
1951. Observations on litter fall and foliage nutrient content of some Pacific Northwest tree species. J. Forest. 49: 914-915.

PNW-83

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SURVIVAL OF *PORIA WEIRII* IN
CONIFER, ALDER, AND MIXED CONIFER-ALDER STANDS

by

Earl E. Nelson, Plant Pathologist



ABSTRACT

Cubes of Douglas-fir heartwood naturally infected with *Poria weirii* were buried for up to 18 months in soil beneath stands of conifers, alder, and mixed alder and conifers. Survival of the fungus under the pure conifer stand was better than under either of the alder-containing stands. It is proposed that lower survival in alder soils is due to high levels of nitrate nitrogen. Many fungi, bacteria, and Actinomycetes competing with *P. weirii* for soil nutrients are able to use this form of nitrogen while *P. weirii* cannot. This difference in physiologies could be a major reason for higher mortality of *P. weirii* in alder soils.

INTRODUCTION

Poria weirii Murr., the cause of a destructive root disease of conifers in the Northwest, destroys 32 million cubic feet of Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] annually in western Oregon and Washington.^{1/}

^{1/} Childs, T. W., and Shea, K. R. Annual losses from diseases in Pacific Northwest forests. Pacific Northwest Forest & Range Exp. Sta. U.S. Forest Serv. Resource Bull. PNW-20, 19 pp. 1967.

Survival of *P. weirii* in roots and stumps of harvested stands and reinfection of ensuing reproduction are responsible for the continuation of this root disease at highly destructive levels. Nelson^{2/} suggests that antagonistic micro-organisms are responsible for the eventual replacement of *P. weirii* in these residues. Other studies at the Forestry Sciences Laboratory and Oregon State University^{3/ 4/} indicate that red alder (*Alnus rubra* Bong.), a nonleguminous nodulated tree, may play an important role in biological control of *P. weirii* root rot.

Soils from stands containing a large proportion of red alder have relatively large amounts of nitrogen combined as nitrate, a form used by many microbes but not usable by *P. weirii* which lacks the enzyme, nitrate reductase.^{5/} Consequently, in these soils, less usable nitrogen is available to *P. weirii*--a disadvantage which could result in reduced longevity of this pathogen.

METHODS

This study was conducted on the Cascade Head Experimental Forest near the Oregon coast in areas originally designed to compare growth of pure conifer, pure red alder, and mixed alder-conifer stands. Conifers in the mixed and pure conifer stands include Douglas-fir, western hemlock [*Tsuga heterophylla* (Raf.) Sarg.], and Sitka spruce [*Picea sitchensis* (Bong.) Carr.]. All three stands were established in 1937. After 40 years, basal areas of the alder, conifer, and mixed stands were 156, 268, and 221 cubic feet, respectively.

^{2/} Nelson, Earl E. Factors affecting survival of *Poria weirii* in small buried cubes of Douglas-fir heartwood. Forest Sci. 13:78-84. 1967.

^{3/} Li, C. Y., Lu, K. C., Trappe, J. M., and Bollen, W. B. Selective nitrogen assimilation by *Poria weirii*. Nature (London) 213(5078):814. 1967.

^{4/} Bollen, Walter B., Chen, Chi-Sin, Lu, Kuo C., and Tarrant, Robert F. Influence of red alder on fertility of a forest soil--microbial and chemical effects. Oreg. State Univ. Forest Res. Lab. Res. Bull. 12. 61. 1967.

^{5/} See footnote 3.

Soils beneath all stands are Astoria-like Sols Bruns Acides developed from deeply weathered tuffaceous siltstone of Eocene epoch and have been described in detail by Franklin et al.^{6/} A complete description of vegetation of the three stands has also been published.^{7/}

In each of the above three stands, three 3- by 6-foot plots gridded at 1-foot intervals were established. In June 1966, 2-inch cubes were cut from heartwood of Douglas-fir naturally decayed by *P. weirii*^{8/} and 18 buried on each of the nine plots. The decayed cubes were buried to a depth of 9 inches by driving a 3-1/4 inch stainless steel tube into the soil, extracting the core, placing a cube at the bottom of the hole, and returning and lightly tamping the extracted core in place. This procedure resulted in minimal soil disturbance.

After 3 and 6 months, three cubes (and after 12 and 18 months, 6 cubes) were removed at random from each plot. Each cube was brushed clean in running tapwater and split in half approximately along the radial plane. Small chips were taken aseptically from four points on the freshly split surface (fig. 1) and placed on malt agar slants. After 10 to 20 days, developing *P. weirii* colonies were identified.

RESULTS AND DISCUSSION

Survival of *P. weirii* in the cubes was always greater in the conifer stand than in either the alder or mixed alder-conifer stands

^{6/} Franklin, Jerry F., Dyrness, C. T., Moore, Duane G., and Tarrant, Robert F. Chemical soil properties under coastal Oregon stands of alder and conifers. In The biology of alder: Proceedings of a symposium of the Northwest Scientific Association. J. M. Trappe, J. F. Franklin, R. F. Tarrant, and G. M. Hansen [eds.]. (In press.)

^{7/} Franklin, Jerry F., and Pechanec, Anna A. Vegetational comparison of adjacent alder, conifer, and mixed alder-conifer communities. In The biology of alder: Proceedings of a symposium of the Northwest Scientific Association. J. M. Trappe, J. F. Franklin, R. F. Tarrant, and G. M. Hansen [eds.]. (In press.)

^{8/} Representative decayed cubes were shown to contain viable *P. weirii* by culturing of small chips taken aseptically from a freshly split surface of each selected cube.

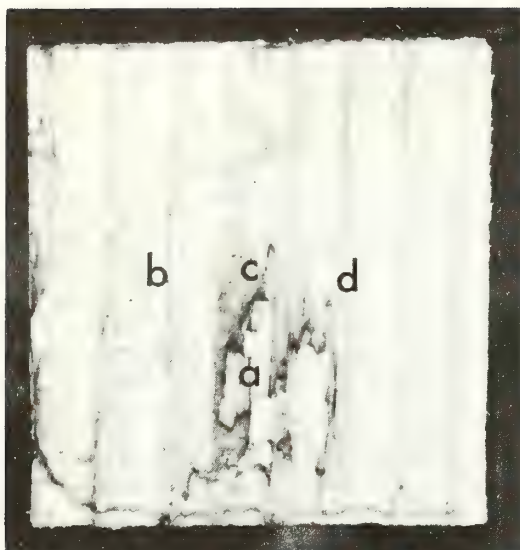


Figure 1.--Split cube showing four points from which cultures were made (a, b, c, and d). The cube was split by driving a chisel a short distance into the upper transverse surface.

except in the sample from the alder stand at 6 months (fig. 2). After 18 months, the fungus survived only in the conifer stand. Although these decayed cubes are much smaller than roots and stumps of harvested stands where *P. weirii* would almost certainly survive longer, it is likely that the effect of stand composition would be similar.

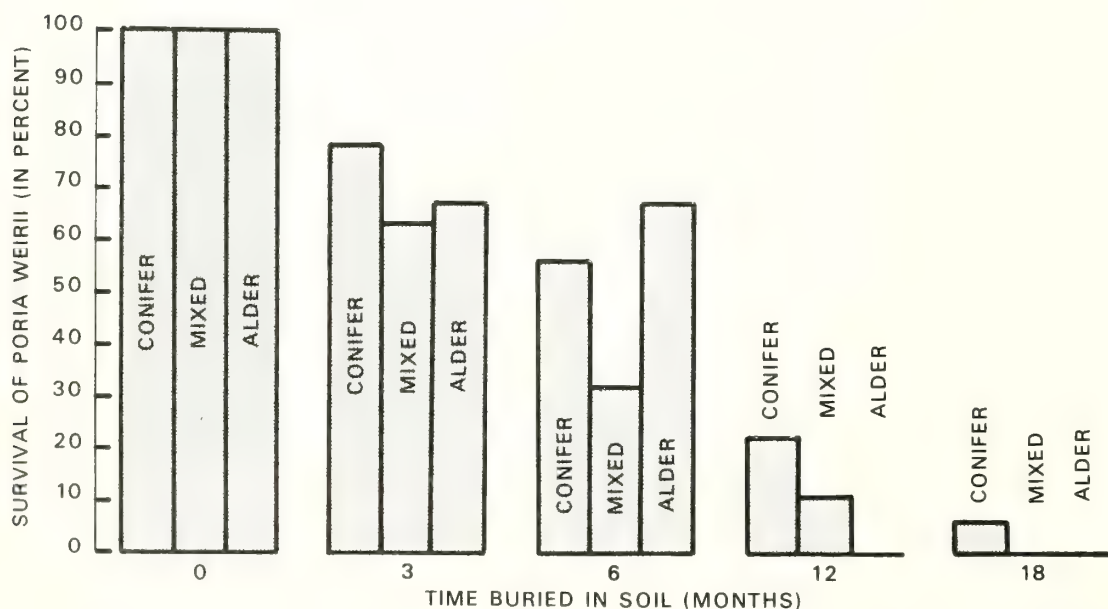


Figure 2.--Survival of *Poria weirii* in 2-inch wood cubes buried in three stands. (Percentages at 3 and 6 months are computed from nine cubes each time; at 12 and 18 months, from 18 cubes each time.)

The action of antagonistic micro-organisms probably is primarily responsible for failure of *P. weirii* to survive in wood in soil.^{9/} During one year, Bollen et al.^{10/} found that soil nitrate nitrogen was always higher in both the alder and mixed alder-conifer stands than in the pure conifer stand. Most soil micro-organisms competing with *P. weirii* for nutrients are able to utilize nitrate as a source of nitrogen. The inability of *P. weirii* to utilize nitrate could be a significant factor in its ability to survive. Whether or not relative abundance of nitrate under alder is the major factor reducing longevity of *P. weirii* can only be speculated.

Conclusions from this study, while encouraging, must be accepted with some reservation. Further studies are needed with greater replication in areas where design does not seriously limit statistical procedures. Trends found in the present study, however, give hope to foresters that *P. weirii* root rot of Douglas-fir can be reduced through natural controls and forest management.

^{9/} See footnote 2.

^{10/} See footnote 4.

PNW-84

August 1968

SPRING-SEASON DEER BROWSING OF DOUGLAS-FIR ON
THE CAPITOL FOREST IN WESTERN WASHINGTON

by

Glenn L. Crouch, *Principal Plant Ecologist*

ABSTRACT

Deer started browsing Douglas-fir shortly after bud burst began and continued browsing for about 1 month. Douglas-fir was eaten despite abundant new growth on many plant species that deer prefer in late spring and early summer. The beginning and ending of tree browsing did not seem to be related to any visual growth-stage characteristic except bud burst. Leaders were growing rapidly when browsing began and ended. Availability of other vegetation in similar stages of development also appeared unrelated to Douglas-fir browsing.

This paper reports results of a series of closely spaced observations of deer browsing obtained during exploratory work to develop methods for use in a more extensive, long-term study of deer/Douglas-fir relationships. The work was conducted from mid-April through July 1967 on two tracts of land about 15 miles southwest of Olympia, Washington. The areas are located in the 72,000-acre Capitol Forest which is managed by the Washington State Department of Natural Resources.

The logging history of the Capitol Forest is long and complex. Timber harvesting began under private ownership before 1900 and continued through the 1930's. Wildfires and reforestation failures have

resulted in stands of mixed ages composed mainly of second-growth Douglas-fir. Many acres are still understocked. Some are overgrown with undesirable hardwoods and are currently under intensive rehabilitation.

STUDY AREA

Each of two study sites consisted of about 1 acre. "Maple Flats" was on a site previously occupied by a closed stand of vine maple (*Acer circinatum*). The hardwoods had been hand-cleared and the area experimentally planted with Douglas-fir in February 1964 as part of a survival and growth study.^{1/}

The second tract, known here as Porter Ridge, is about 7 miles west of Maple Flats and was planted most recently in the late 1950's.

From appearances of the trees, both areas had sustained intensive deer browsing during the past 2 or more years. The monthly browsing pattern on newly planted Douglas-fir at Maple Flats was investigated in 1964 and 1965.^{2/}

During both years, deer browsed Douglas-fir in the late spring and early summer. A similar browsing sequence probably occurred on Porter Ridge.

METHODS

For this study, randomly selected Douglas-fir trees were repeatedly examined for signs of browsing at 7- to 10-day intervals starting in mid-April and ending on August 2, 1967. Fifty trees were inspected at Maple Flats and 25 on Porter Ridge. Incidences of browsing were recorded without regard to amounts of foliage removed.

In addition, shrubs were tagged and ground plots installed to determine which plants were available and eaten by deer at times when they browsed Douglas-fir. Browsing on tall shrubs was evaluated by tagging one branch available to deer on the two shrubs nearest each sample tree. Browsing on species of *Rubus* was determined by examining individual plants in circular mil-acre plots centered at each tree marker stake.

^{1/} Unpublished data from Washington State Department of Natural Resources on file at the Forest Land Management Center, Olympia, Wash.

^{2/} Unpublished data held by E. J. Dimock II at the Forestry Sciences Laboratory, Olympia, Wash.

Browsing of herbaceous species was determined by periodic examinations of all plants growing in circular 3.1-square-foot plots (fig. 1). Plots were established adjacent to 20 sample trees on Maple Flats and next to 10 trees at Porter Ridge.



A



B

Figure 1.-- Herbage sampling plot at Maple Flats. (A) taken in April 1967 shows little deer forage; (B) taken in June 1967 shows abundance of forage

In mid-June, percent cover of low-growing plants was estimated in each herbage utilization plot by use of cover classes adapted from Daubenmire.^{3/} Cover of taller shrubs was estimated in circular milacre

^{3/} Daubenmire, R. F. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-49. 1959.

plots centered at the same 20 and 10 trees as above. Most plants are named according to Hitchcock^{4/} and Hitchcock et al.^{5/}

Pellet group counts were used to confirm the presence of deer during the study period.

RESULTS

Douglas-fir.--At study installation, the 50 trees at Maple Flats averaged 27.0 ± 2.1 inches ($p = 0.05$) in height. The 25 trees at Porter Ridge were taller, averaging 42.3 ± 4.9 inches. Measurements during the final examination showed that Maple Flats trees were then 34.1 ± 2.9 inches high, and those on Porter Ridge were 63.1 ± 7.1 inches. Trees on both areas were still growing when last measured so these values do not represent final heights for the year.

Bud burst was first noted on May 19 at Maple Flats when one tree met the arbitrarily set requirement that the terminal plus at least 10 percent of the lateral buds be opened. Seven days later, shoots on more than 20 percent of the trees at Maple Flats and almost 40 percent of those on Porter Ridge were growing (fig. 2).

Tree browsing was first observed June 12 on both areas (fig. 3). By that time, shoot growth had begun on more than 80 percent of the sample trees. Between June 12 and the preceding inspection 10 days earlier, more trees were browsed than during any succeeding interval. Actually, nearly half of all the browsing recorded during the study took place during that period. On Porter Ridge, browsing continued at a relatively high rate for 2 more weeks, until June 30, and then stopped abruptly. The higher rate continued 1 week longer at Maple Flats and then declined there also. No browsing was detected at either location after July 17, and only one tree was browsed after July 7. Unbrowsed leaders were measured at Porter Ridge on July 7, 17, and August 2 to determine if the reduction in browsing observed on July 7 might be associated with a declining growth rate of shoots. Mean leader lengths of 13.6, 18.0, and 23.0 inches on respective dates indicated that shoots were still growing rapidly almost 3 weeks after the latest instance of browsing.

^{4/} Hitchcock, A. S. Manual of the grasses of the United States. Ed. 2, rev. by Agnes Chase. U.S. Dep. Agr. Misc. Pub. 200, 1051 pp.

^{5/} Hitchcock, C. L., Cronquist, A., Owenby, M., and Thompson, J. W. Vascular plants of the Pacific Northwest. Univ. Wash. Pub. Biol. Vol. 17, parts 2, 3, 4, and 5. Seattle: Univ. Wash Press. 1955-64.

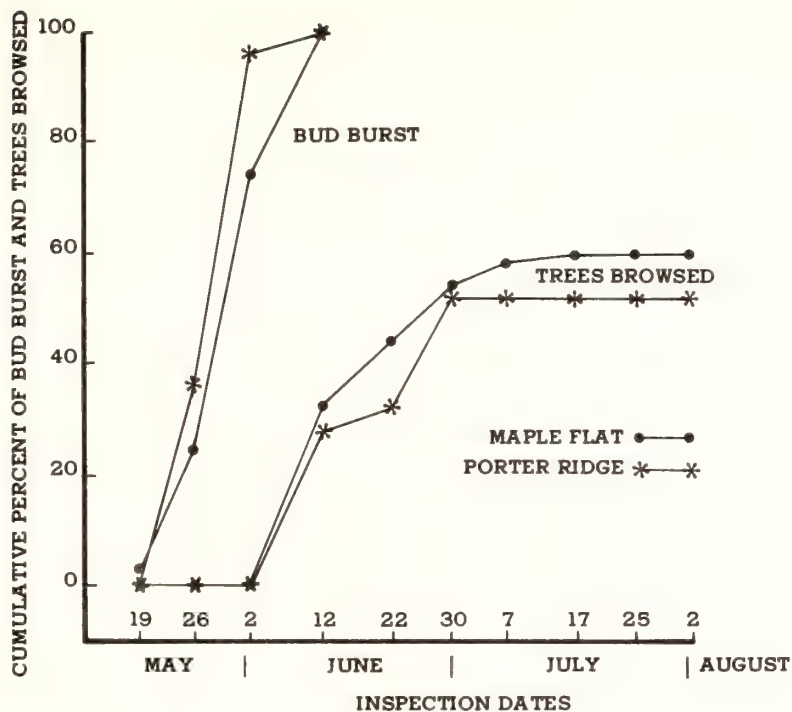


Figure 2.--Cumulative patterns of bud burst and browsing of Douglas-fir

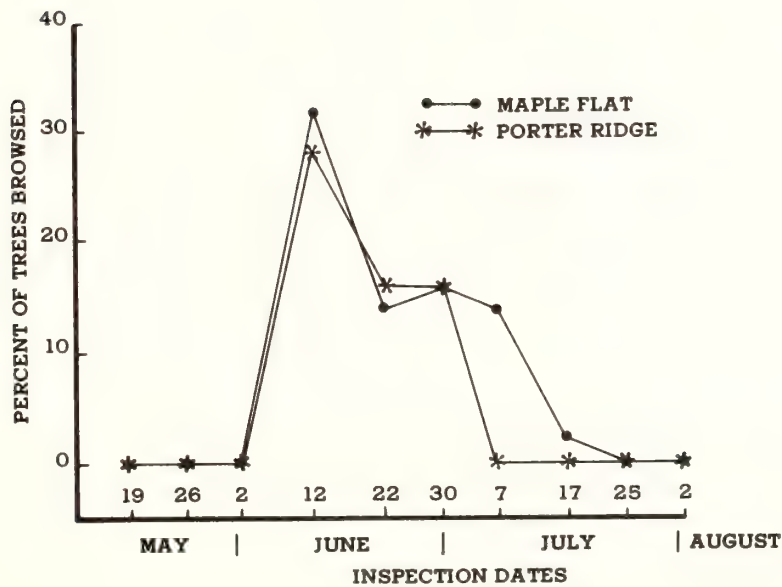


Figure 3.--Chronological patterns of browsing of Douglas-fir

In all, 60 percent of the trees at Maple Flats and 52 percent at Porter Ridge were browsed to some degree (fig. 2). Thirteen percent of all trees were browsed more than once.

Other plants.--Although many of the same plant species were present on both areas, the dominants and the average cover of most species were strikingly different (table 1). The dominant hardwood at Maple Flats was cascara (*Rhamnus purshiana*). Individual cascara plants were well distributed over the area and reached heights of 8 feet or more. Repeated clipping by mountain beaver (*Aplodontia rufa*) kept crown cover relatively low despite large numbers of plants.

Plants of *Vaccinium* were the more abundant taller shrubs at Porter Ridge. Most were *V. parvifolium*, but many *V. ovalifolium* were also present.

Periodic observations of seasonal plant development indicated that leaf growth on woody plants began about 2 weeks before Douglas-fir bud burst. Most herbaceous species were also partially leafed out by that time. When Douglas-fir browsing began, those plant species favored by deer were estimated to be at or beyond the half-leafed stage. During the period when conifers were browsed, deer fed mainly on leaves and new twigs of woody plants and Douglas-fir (table 1 and fig. 2). Except for the browsing of flower buds and heads of *Hypochaeris radicata*, use of herbaceous plants was almost nonexistent.

CONCLUSIONS

Although the findings presented here resulted from a single, 1-year small-scale study, we believe they indicate a browsing pattern that may occur on many areas in the Douglas-fir region. Preliminary results of studies in the Coast Ranges of west-central Oregon suggest that intensive browsing of Douglas-fir in many clearcut units may also be limited to a short period following bud burst.^{6/} Browning and Lauppe^{7/} report a similar pattern in northwestern California.

Deer browsed Douglas-fir despite abundant new growth on many species of plants that deer prefer in the late spring and early summer.^{8/}

^{6/} Unpublished data held by the writer at the Forestry Sciences Laboratory, Olympia, Wash.

^{7/} Browning, B. M., and Lauppe, E. M. A deer study in a redwood-Douglas-fir forest type. Calif. Fish and Game 50:132-147. 1964.

^{8/} Brown, E. R. The black-tailed deer of western Washington. Wash. State Game Dep. Biol. Bull. 13, 124 pp. 1961.

Table 1.—Ground cover composition and forage utilization on two study areas; Capitol Forest, Washington, 1967

Species	Percent cover		Maple Flats		Porter Ridge	
	Maple Flats	Porter Ridge	Apr. 17 to Aug. 2	June 2 to July 7	Apr. 17 to Aug. 2	June 2 to July 7
----- Percent of shrubs with browsing -----						
Trees and taller shrubs:						
<i>Pseudotsuga menziesii</i>	(1/)	(1/)	60	58	52	52
<i>Rhamnus purshiana</i>	8	0	1	0	0	0
<i>Acer circinatum</i>	2	0	33	29	0	0
<i>Vaccinium parvifolium</i>	<1	2	100	0	60	55
<i>Corylus cornuta</i>	<1	0	0	0	0	0
<i>Salix scouleriana</i>	0	2	0	0	85	77
<i>Vaccinium ovalifolium</i>	0	<1	0	0	100	33
----- Percent of plots with browsing -----						
Low shrubs and herbs:						
<i>Pteridium aquilinum</i>	20	2	0	0	0	0
<i>Rubus ursinus</i>	17	9	0	0	37	26
<i>Rubus spectabilis</i>	17	1	19	19	50	40
<i>Vancouveria hexandra</i>	17	0	0	0	0	0
<i>Chrysanthemum leucanthemum</i>	10	0	0	0	0	0
<i>Holcus lanatus</i>	6	16	0	0	0	0
<i>Hypochaeris radicata</i>	6	40	33	33	80	80
<i>Lotus crassifolius</i>	5	0	0	0	0	0
<i>Elymus glaucus</i>	3	<1	8	0	50	0
<i>Crepis capillaris</i>	2	<1	0	0	0	0
<i>Senecio jacobaea</i>	2	<1	0	0	0	0
<i>Anaphalis margaritacea</i>	1	1	0	0	0	0
<i>Solidago canadensis</i>	1	0	0	0	0	0
<i>Galium triflorum</i>	1	0	0	0	0	0
<i>Luzula</i> spp.	<1	1	0	0	0	0
<i>Asarum caudatum</i>	<1	6	0	0	0	0
<i>Cirsium</i> sp.	<1	1	0	0	0	0
<i>Rumex acetosella</i>	<1	1	0	0	0	0
Total plant cover ^{2/}	89	60				
Bare ground	1	0				
Litter	96	69				

^{1/} Not estimated.^{2/} 21 additional plant species were recorded but only those averaging at least 1 percent of cover on either area are shown.

Deer did not browse all or even moderate amounts of any reportedly preferred species. In fact, browsing was so inconspicuous on most species, except Douglas-fir, that relatively minute examinations were required to detect use.

The initiation and cessation of tree browsing did not appear to be related to any visible growth-stage characteristics except bud burst. Leaders were growing rapidly when browsing began and ended. Availability of other vegetation in similar stages of development appeared to have no effect on Douglas-fir browsing.

If the short-term pattern of spring-season browsing described here proves to be widespread, then reappraisal of current deer damage control practices might be appropriate since growing-season protection may only be needed for a few weeks following bud burst.

Pacific
North
West Forest and Range Experiment Station
Forest Service **RESEARCH NOTE**

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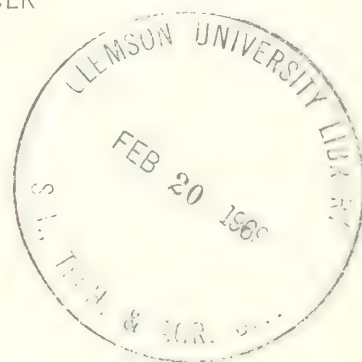
DETERMINATION OF NUCLEOPOLYHEDRON COUNTS AND SIZE FREQUENCY
DISTRIBUTIONS BY MEANS OF A COULTER TRANSDUCER^{1/}

by

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and

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Abstract

A Coulter counter, model B, with upper and lower threshold discriminators and a 30-micron aperture tube, can be used for the enumeration of nucleopolyhedra in suspensions--either pure or with varying amounts of impurities; also can establish size frequency distributions of viral inclusion bodies. Procedures are described in detail and illustrated.

Introduction

Particle counts have been utilized as a basis for standardizing suspensions of inclusion bodies of nucleopolyhedrosis virus. In insect control experiments, the number of polyhedral inclusion bodies in a given weight or volume of a nucleopolyhedrosis virus preparation

^{1/} Mention of a proprietary name does not imply endorsement or approval of the product by the U.S. Department of Agriculture to the exclusion of others which may also be suitable.

is frequently used as an indicator of the potency of such preparation. For example, the two following units are in current use in the United States: viral unit (VU) = 1×10^9 nucleopolyhedra; and larval equivalent (LE) = 6 VU = 6×10^9 nucleopolyhedra (Allen 1967; Woodall and Ditman 1967).

Experts disagree as to the validity and reliability of polyhedron counts for the estimate of the activity of a viral preparation in lieu of biological assay (determination of the LD₅₀ or ID₅₀).^{2/} Our position is that the polyhedron count can be, at times, quite misleading, particularly when used for comparison of the potency of different batches of viral material. However, once a correlation has been established between polyhedron count and activity of a viral preparation, the count may be used quite satisfactorily in lieu of the LD₅₀ or ID₅₀, particularly when a rapid indirect titration method is needed (as under field conditions).

Our laboratory has adopted two counting procedures: One is microscopic, and the other is electronic and requires elaborate equipment. The microscopic procedure, with a counting chamber (hemacytometer), is simple and can be recommended for the occasional determination of polyhedron counts, particularly under field conditions. A rapid automated procedure, on the other hand, is very useful for the recurring determination of inclusion-body counts of large series of preparations in the laboratory. The automated procedure used in our laboratory, as well as its advantages and disadvantages, will be outlined. Particle-size frequency distribution curves of some typical preparations will be presented.

Materials and Methods

Nucleopolyhedron Suspensions

The suspensions of nucleopolyhedra used in this study were prepared from tissue homogenates of larvae of the Douglas-fir tussock moth (*Hemerocampa pseudotsugata*) which were inoculated with nucleopolyhedrosis virus. The tissues were finely ground in buffered saline^{3/} with the addition of 0.00075 percent sodium dioctyl

^{2/} LD₅₀ or ID₅₀ is the dose which produces a response in 50 percent of the test subjects. If the response is death the dose is called median lethal dose (its symbol is LD₅₀); if the response is progressive infection, the dose is called median infective dose (ID₅₀).

^{3/} NaCl, 9 grams; 2-amino-2-(hydroxymethyl)-1,3 propanediol with hydrochloride (Trizma 7.1), 1.558 grams; distilled H₂O, to 1,000 ml.; HCl, 0.1 N, as needed to adjust the pH at 7.0 (at 25° C).

sulfosuccinate, a surface active agent. These suspensions were cleaned by centrifugation in sucrose density gradient columns.

One series of six paired counts (particle counting chamber and Coulter counter) was performed with a suspension obtained by isopycnic density gradient centrifugation as described by Martignoni (1967). This suspension was very pure, as revealed by dark-field microscopic examination and by bioassay. The number of particles other than polyhedra was 2 percent of the gross count; i.e., of all counted particles in the size range of the inclusion bodies. The main purpose of this series of counts with a purified suspension was to test the agreement between electronic counts and counts performed with a microscope counting chamber.

A second series of six paired counts was performed with six different preparations containing varying amounts of impurities. The number of particles other than polyhedra varied between 1.5 and 7.9 percent of the gross count; i.e., of all counted particles in the size range of the inclusion bodies. These suspensions were prepared as follows: Tissue homogenates were floated on columns of sucrose solutions (650 and 720 milligrams per milliliter) and spun for 1 to 2 hours at 25,000 revolutions per minute (maximal gravity field 112,000 x gravity). The fraction at the interface between the two sucrose solutions was collected, rinsed, and appropriately diluted with buffered saline. The main purpose of this second series of counts was to test the accuracy of the method when applied to preparations containing varying amounts of impurities, both within and outside the size range of the inclusion bodies.

Microscopic Counting Procedure

All microscope counts were made with one Spencer Bright Line counting chamber with double improved Neubauer ruling (No. 1492, American Optical Company, Buffalo, N. Y.). The chamber was filled with the polyhedron suspension in accordance with routine blood-cell counting procedures. The filled chamber was placed on the stage of a phase contrast microscope equipped with a 16X objective. The inclusion bodies were allowed to settle for 5 minutes. Six replicate counts were made for each preparation: Each count covered an area of 5 square millimeters, in separate single chambers. Thus, the total counting area was 30 square millimeters. In no instance did the number of polyhedra per square millimeter exceed 50. The polyhedron count was computed as follows:

$$\text{Number of polyhedra per microliter of stock suspension} = \frac{\text{Total number of polyhedra counted} \times \text{dilution} \times 10}{30}$$

The counts were performed independently by two observers who were quite familiar with the appearance of nucleopolyhedra as seen under phase contrast. These two observers used their judgment in rejecting certain particles which did not appear to be nuclear polyhedra. This

decision was carried out rather frequently (and independently) when the suspension contained particulate impurities in the same size range as the viral inclusion bodies.

Electronic Transducer Counting Procedure

To enumerate polyhedra in a suspension which also contains other particles in the approximate size range of the polyhedral inclusions, the following procedure was developed: (1) determine the total number of particles of a size range encompassing the polyhedron size distribution (gross count); (2) dissolve the nucleopolyhedra by treatment with alkali and ultrasound and take a second count (insoluble particle count); (3) obtain the number of nucleopolyhedra in the suspension by subtraction of the insoluble particle count from the gross count (net count).

The instrument used was a Coulter counter, model B, with upper and lower threshold discriminators, an aperture tube with 30-micron orifice, and a sampling volume of 50 microliters. Operation of the model B counter is described in detail in the Coulter "Instruction and Service Manual" (Coulter Electronics, Inc. 1966). All instrument counts were corrected for background particles and coincidence loss. A coincidence correction chart for the 30-micron aperture was supplied by Coulter Electronics, Inc. Dilutions of the polyhedron suspensions were such that in no instance the number of polyhedra per 50-microliter sample exceeded 23,000. The instrument time required for each count (50-microliter sample) was 14 seconds. Ten repeat counts in pairs of alternating polarity were taken for each preparation.

For counting with the electronic transducer, the suspensions were prepared with the following buffered saline:

NaCl	9 grams
2-amino-2-(hydroxymethyl)- 1,3 propanediol with hydrochloride (Trizma 7.1)	1.558 grams
Distilled H ₂ O	to 1,000 milliliter
HCl, 0.1 N	as needed to adjust the pH at 7.0 (at 25° C.)

Before use, the conductive solution was filtered through GS membranes (pore size 0.22 micron; Millipore Filter Corp, Bedford, Mass.).

The following formula was used for computation of the net nucleopolyhedron count (*C*):

$$C = (a - a_{bp} + a_{cl}) - (b - b_{bp} + b_{cl})$$

where a is the gross count, b the insoluble particle count, a_{bp} and b_{bp} the respective background particle counts, a_{cl} and b_{cl} the respective coincidence losses. A step-by-step procedure for the determination of these quantities follows.

1. Rinse a clean 100-milliliter beaker with distilled water and pour about 80 milliliters of buffered saline in it. Place on platform in sample stand and stir.
2. Make five pairs of 50-microliter counts. Stop stirrer during each counting period. Compute and record mean count. This is the background particle count, a_{bp} .
3. Measure 49 milliliters of the saline and return it to the same beaker, after discarding the surplus.
4. To the 49 milliliters of saline add 1 milliliter of the test suspension of nucleopolyhedra, diluted to provide an instrument count between 5,000 and 25,000 per 50-microliter sample. Place on platform in sample stand and stir.
5. Make five pairs of 50-microliter counts. Stop stirrer during each counting period. Compute mean count. This is a .
6. Read the coincidence correction factor in the Coulter coincidence correction chart (for 30-micron apertures). (This factor varies between 0.4 and 2.1 percent for instrument counts between 5,000 and 25,000.) Multiply the instrument count by this factor. This is a_{cl} .
7. Place 1 milliliter of the test suspension of nucleopolyhedra (the same as used in step 4) in a Kolmer tube.
8. Add 1 milliliter of an alkaline solution prepared by mixing equal volumes of 0.2 molar NaOH and 0.1 molar Na_2CO_3 + 0.2 molar NaCl. [Both stock solutions are made freshly every second week and filtered through HA membranes--pore size 0.45 micron; Millipore Filter Corp.] Cover the tube with a plastic membrane and let stand for 5 minutes at room temperature with occasional agitation.
9. Expose the tube to ultrasound by immersing it for 10 minutes in the tank of an ultrasound generator (80 kilocycles per second at 80 watts).
10. Make a background count for the saline (as in step 2) and record. This is b_{bp} .

11. Measure 48 milliliters of this saline and return it to the same beaker, after discarding the surplus.
12. To this volume of saline add the 2 milliliters of treated suspension (from step 9). Place on platform in sample stand and stir.
13. Make five pairs of 50-microliter counts. Stop stirrer during each counting period. Record mean count. This is b .
14. Determine b_{c1} as in step 6.
15. Determine C , using the equation outlined above.

For very clean nucleopolyhedron suspensions--as obtained by repeated isopycnic density gradient fractionation (Martignoni 1967)-- b is equal or very close to b_{bp} and, consequently, b_{c1} is equal or very close to zero. Thus, steps 7 to 14 inclusive can be omitted, and

$$C = a - a_{bp} + a_{c1}.$$

Considerable time can be saved by use of a flow-through cuvette (Bull 1967), particularly if many suspensions have to be handled in a relatively short time interval.

Determination of Size Frequency Distributions

Size distribution data were obtained from very clean suspensions of nucleopolyhedra in accordance with procedures described in the Coulter "Instruction and Service Manual" (Coulter Electronics, Inc. 1966). The upper threshold mode switch was placed in the "locked" position, the upper threshold dial was set at 50, and successive counts were taken at lower threshold intervals of five divisions. With such procedure, 20 windows of five dial divisions each are obtained. Calibration of the Coulter counter was performed with monodisperse polystyrene latex spheres (diameter, 2.96 microns; Dow Chemical Co., Midland, Mich.).

Results and Discussion

Polyhedron Counts

Tables 1 and 2 summarize the results of the two series of paired counts.

The relation between the two variables (microscopic counts and electronic counts) was measured by means of the coefficient of correlation. For the purified preparation, $r = 0.9997$, and for the series of impure preparations, $r = 0.9947$. Both coefficients are highly significant, and thus, we can state that the two variables are very closely related. This is evident also from an inspection of figures 1 and 2.

Table 1.--Results of one series of paired counts (microscopic and electronic) with a purified nucleopolyhedron suspension^{1/}

Count number	Microscopic count		Electronic count	
	Number of polyhedra counted	Number of polyhedra per microliter	Number of polyhedra counted	Number of polyhedra per microliter
1	327	5,450	54,480	5,448
2	589	9,817	100,248	10,025
3	818	13,633	137,170	13,717
4	1,022	17,030	166,942	16,694
5	1,187	19,783	195,787	19,579
6	1,304	21,733	215,450	21,545

^{1/} Microscopic counts are the average of six counts, each of 5 square millimeters. Electronic counts are the average of 10 repeat counts in pairs of alternating polarity.

Table 2.--Results of one series of paired counts (microscopic and electronic) with six impure nucleopolyhedron suspensions^{1/}

Count number	Microscopic count		Electronic count	
	Number of polyhedra counted	Number of polyhedra per microliter	Number of polyhedra counted	Number of polyhedra per microliter
1	450	7,500	75,127	7,513
2	508	8,467	83,545	8,355
3	685	11,417	113,858	11,386
4	697	14,463	118,458	14,748
5	1,118	18,633	174,958	17,496
6	1,261	21,017	215,320	21,532

^{1/} Microscopic counts are the average of six counts, each of 5 square millimeters. Electronic counts are the average of 10 repeat counts in pairs of alternating polarity.

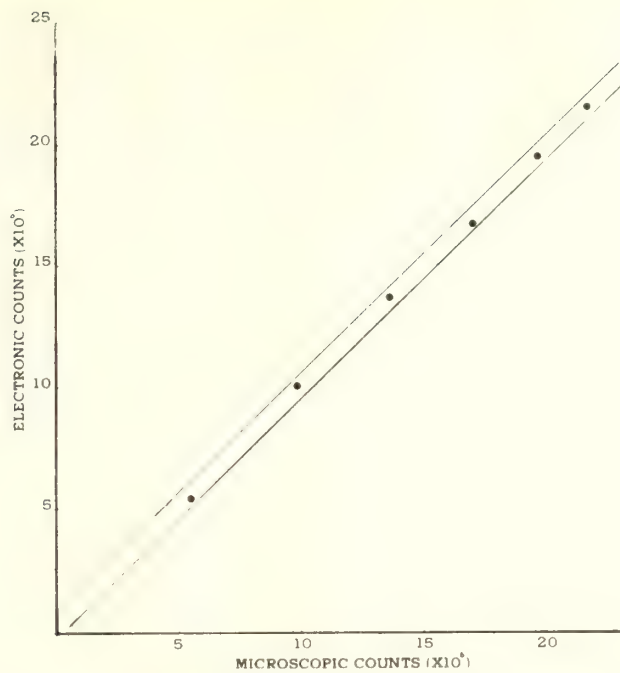


Figure 1.--Scatter diagram of microscopic counts of nucleopolyhedra in purified suspensions, plotted against electronic counts, with 0.95 confidence limits.

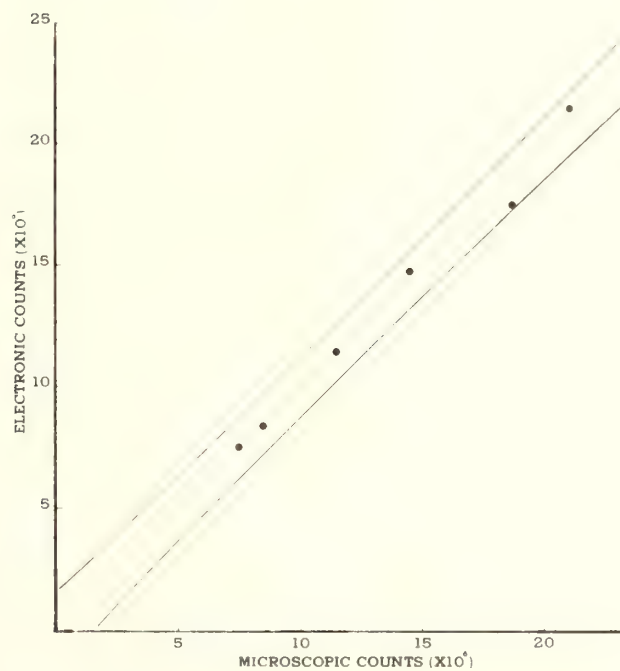


Figure 2.--Scatter diagram of microscopic counts of nucleopolyhedra in six impure preparations, plotted against electronic counts, with 0.95 confidence limits.

There is some slight evidence to indicate less agreement between the two counting methods in the case of the impure suspensions. A *t* test for the difference between the two coefficients of correlation indicates significance at the 10-percent probability level but not at the 5-percent level. This slightly lower correlation between the two methods in the case of the impure preparations may be attributable to the presence of alkali-soluble impurities in the nucleopolyhedra size range and of particles similar to nucleopolyhedra when observed in the microscopic counting chamber. However, for all practical purposes, the electronic method can be considered at least as reliable as the microscopic method, even when the polyhedron suspensions are relatively impure. The electronic method has the advantage of being independent from the decisionmaking process of an observer skilled in the differentiation of nucleopolyhedrosis virus inclusion bodies from other similar particles of nonviral origin.

Tables 1 and 2 also illustrate one of the important advantages of an electronic transducer for particle-counting procedures. The electronic counts were based on actual numbers of counted particles which were approximately 170 times greater than the number of particles counted with the conventional microscopic procedure. The percent standard error of the microscopic counts (which fit a Poisson distribution) is thus considerably reduced by the electronic counting procedure, as shown by the two examples in table 3.

Table 3.--*A comparison of the standard errors of two sets of paired counts (examples from table 2)*

Quantities	Count no. 1		Count no. 6	
	Microscopic	Electronic	Microscopic	Electronic
Mean count, polyhedra per microliter	7,500	7,513	21,017	21,532
Standard error, polyhedra	353	27	593	47
Standard error, percent of mean	4.71	0.36	2.82	0.22

When the suspensions are prepared with raw tissue homogenates, the agreement between the two counting procedures is erratic and, in general, very poor. Electronic counts are usually higher than microscopic counts, possibly because the trained microscopist is rather conservative in deciding what is really a viral inclusion body among a multitude of candidate particles. Also, raw suspensions may contain a high number of alkali-soluble particles of nonviral origin, particles which are

"accepted" as polyhedra with the electronic procedure. It appears that both counting procedures are quite unsatisfactory when the suspensions are extremely impure. For example, four paired counts, performed in our laboratory with one raw suspension of homogenized tissue containing nucleopolyhedra as well as a considerable proportion of insoluble particles in the size range of the polyhedra (17.1 percent of the gross particle count), gave consistently smaller numbers with the conventional microscopic procedure than with the electronic procedure. The microscopic counts averaged 51.4 percent of the corresponding electronic counts. It should be noted, however, that a disagreement of similar magnitude existed when microscopic counts of polyhedra in raw suspensions were performed by two independent observers, as exemplified in table 4!

Table 4.--*Two sets of microscopic counts of nucleopolyhedra from raw suspensions of tissue homogenates (six different preparations obtained from larvae of Hemerocampa pseudotsugata)*^{1/}

Preparations	Polyhedra per mg. dry weight ($\times 10^6$)		Count no. 2 as percent of count no. 1
	Count by observer no. 1	Count by observer no. 2	
A	60	30	50
B	60	18	30
C	50	23	46
D	52	21	40
E	50	21	42
F	48	26	54

^{1/}

The two observers worked independently in two separate laboratories, using essentially similar microscopic counting procedures.

We believe that polyhedron counts of suspensions prepared with raw tissue homogenates are unreliable, and that the biological assay of such suspensions provides a more consistent estimate of the potency of such preparations (e.g., LD₅₀ in nanograms of preparation per gram of larval weight). Microscopic as well as electronic polyhedron counting procedures are accurate and reliable when the inclusion-body suspensions are relatively clean.

Polyhedron Size Distribution

The mean size of nucleopolyhedra from various species of insects has been determined with optical and electron microscopes by a number of investigators. The measurements were usually limited to relatively small samples (50 to 100 inclusion bodies).

The circuitry of the model B Coulter counter permits all particles of a size between two selected threshold levels to be counted and registered on glow-type decade counters. The upper and lower threshold discriminators screen out particle counts above and below a predetermined size. By means of this circuitry it is possible to determine accurately size distributions of large samples from a population of particles.

The size distributions of four different batches of nucleopolyhedra obtained from larvae of *Hemerocampa pseudotsugata* are illustrated in figure 3. The data relevant to the four samples are presented in table 5.

Table 5.--*Sample size, mean volume, and volume range of four nucleopolyhedron preparations, as determined with the Coulter transducer*

Preparation number	Number of polyhedra sampled	Mean volume of polyhedra, μ^3	Percent particles in volume (μ^3) range indicated
17	5,337	5.5	98.1 (1.6 to 10.6)
18	10,376	4.5	95.2 (1.6 to 10.6)
19	2,560	5.6	97.7 (1.6 to 10.6)
20	13,480	3.9	99.0 (0.9 to 9.3)

Electron microscope measurements are frequently standardized by means of a linear reference; e.g., a grating replica with 28,800 lines per inch. The calibration of our Coulter counter was based on the volume of spheres of monodisperse polystyrene latex sized by electron microscopy (average particle diameter 2.96 microns; standard deviation 0.016 micron). Mr. R. B. Addison, of our Forestry Sciences Laboratory, measured 50 particles of this latex suspension, using a Philips EM-200 microscope and a grating replica (28,800 lines per inch) as a primary standard. The microscope was used with only one condenser and with the lowest usable beam intensity in order to keep irradiation of the specimen to a minimum. The mean diameter of this sample was consistent

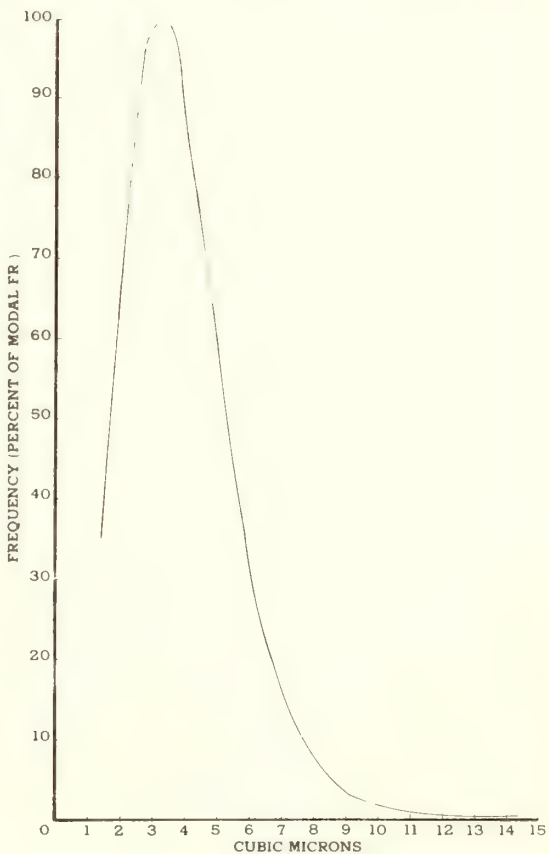
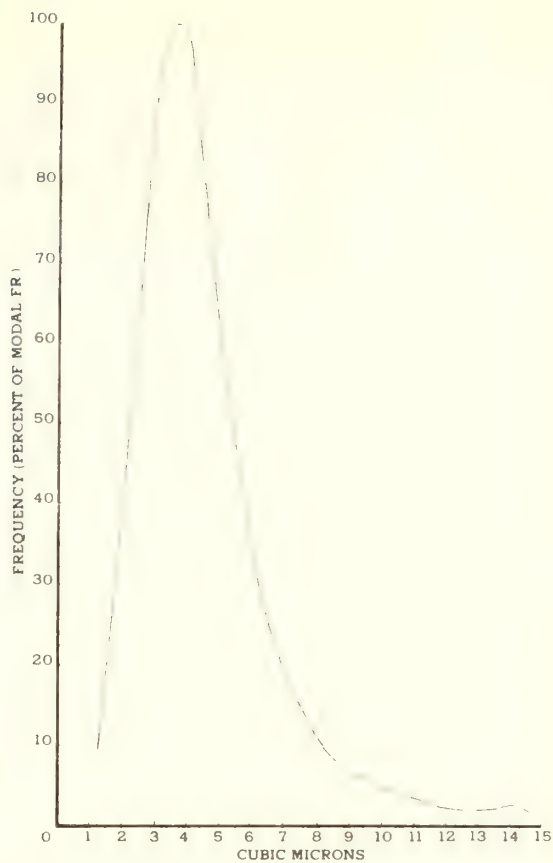
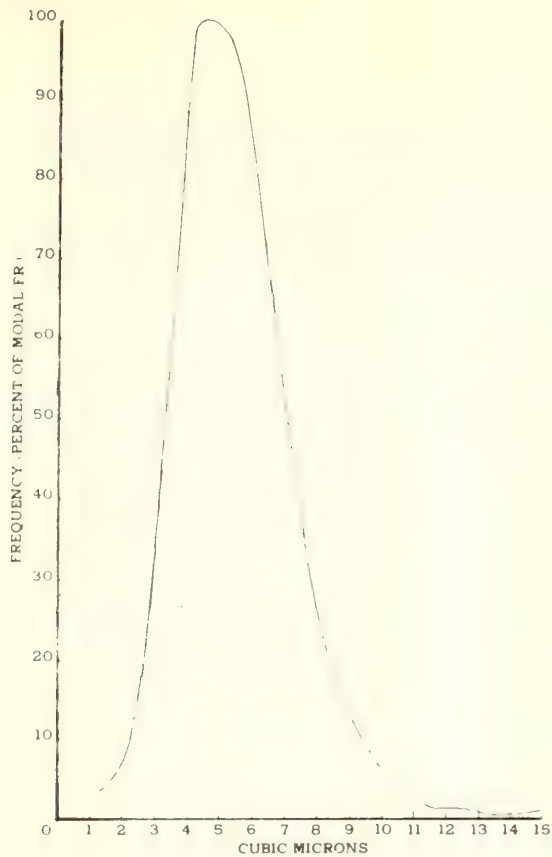


Figure 3.--Relative polyhedron size distributions (modal frequency = 100) of four different purified preparations. The values on the x-axis are polyhedron volumes in cubic microns.

with that quoted by the manufacturer. Electron microscopic measurement is, at present, the best method available for the primary standardization of particle size distributions (Harvey and Marr 1966). Measurements of arrays of spheres with a phase contrast optical microscope (Kubitschek 1961; Bradford and Vanderhoff 1966) also gave values which did not deviate from the mean diameter estimate provided by the manufacturer.

A comparison of our polyhedron samples with the polyhedra measured by Morris (1963) can only be approximate, since the solid shape of the nuclear inclusion bodies of *Hemerocampa pseudotsugata* is very irregular. Morris found that the average "diameter" of 100 polyhedra measured was 1.5 microns, with a range of 1.2 microns to 2 microns. When allowance is made for the irregular shape of the polyhedra, this "diameter" is not inconsistent with the size of the polyhedra of our sample 20 (see table 5). However, a definitive comparison between samples should be based on identical sizing methods, equipment, and calibration standards to limit the sources of errors inevitably present in all indirect measuring procedures.

Summary

Coulter counts of nucleopolyhedra in purified suspensions and in suspensions containing varying amounts of impurities (up to 7.9 percent in the size range of the inclusion bodies) gave results in good agreement with counts performed with the traditional microscopic counting chamber. Since the sample size is very large in the electronic procedure, the relative standard errors (percent of mean) were reduced by a factor of 10 or more. Paired counts with raw suspensions of inclusion bodies (tissue homogenates containing 17.1 percent particles other than polyhedra in the size range of the inclusion bodies) showed poor agreement between the electronic and microscopic counting procedures. On the other hand, a similar disagreement was detected when two independent observers performed counts using the same procedure (microscopic technique). Polyhedron counts of suspensions containing large amounts of impurities (such as raw tissue homogenates) gave unreliable results by electronic as well as microscopic procedures. In such cases, biological assay remains the only reliable method for the determination of infectivity titers.

The circuitry of the model B Coulter counter permits one to count all particles of a size between two selected threshold levels. Thus it is possible to establish size frequency distributions of batches of nucleopolyhedra based on large numbers of particles (as compared with the 50 or 100 particles conventionally measured by electron microscopists). Four batches of polyhedra from one insect species (*Hemerocampa pseudotsugata*) were found to have similar mean particle volumes and volume frequency distributions when sized by means of a

30-micron aperture. The mean volumes of the polyhedra varied between $3.9 \mu^3$ and $5.6 \mu^3$. The Coulter transducer was calibrated with monodisperse polystyrene latex.

Acknowledgments

We gratefully acknowledge the useful advice of Mr. Floyd A. Johnson, Principal Biometrician, and the assistance provided by Mr. R. B. Addison, who performed the electron-microscopic examination of the latex.

Literature Cited

- Allen, G. E.
1967. Report of second work conference on the utilization of nuclear-polyhedrosis virus for the control of *Heliothis* species. J. Invertebrate Pathol. 9: 447-448.
- Bradford, E. B., and Vanderhoff, J. W.
1966. The use of monodisperse latexes as calibration standards. Amer. Chem. Soc. Abstr. Pap., 151st Meeting, Sect. B, Symp. Particle Size Distributions, Pap. 47, 1 p.
- Bull, B.
1967. A flow-through cuvette for the Coulter counter. Amer. J. Clin. Pathol. 47: 107-108.
- Coulter Electronics, Inc.
1966. Instruction and service manual for the model "B" Coulter counter. Ed. 3, 43 pp. Hialeah, Fla.
- Harvey, R. J., and Marr, A. G.
1966. Measurement of size distributions of bacterial cells. J. Bacteriol. 94: 805-811.
- Kubitschek, H. E.
1961. Optical calibration of some monodisperse polystyrene latexes in arrays. Nature 192: 1148-1150.
- Martignoni, M. E.
1967. Separation of two types of viral inclusion bodies by isopycnic centrifugation. J. Virol. 1: 646-647.
- Morris, O. N.
1963. A nuclear polyhedrosis of *Orgyia pseudotsugata*: Causative agent and histopathology. Can. J. Microbiol. 9: 889-900.
- Woodall, K. L., and Ditman, L. P.
1967. Control of the cabbage looper and corn earworm with nuclear polyhedrosis viruses. J. Econ. Entomol. 60: 1558-1561.

Pacific
North
West Forest and Range Experiment Station
Forest Service **RESEARCH NOTE**

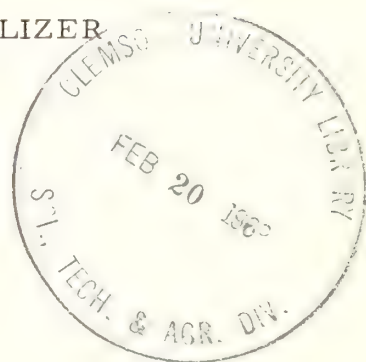
PNW-86

August 1968

GROWTH RESPONSE OF 35-YEAR-OLD,
SITE V DOUGLAS-FIR TO NITROGEN FERTILIZER

by

Donald L. Reukema, *Silviculturist*



ABSTRACT

During the first 4 years following application, addition of 200 to 600 pounds of nitrogen per acre increased height increment 62 percent and d.b.h. increment 79 to 160 percent. Gross basal area increment was greater with heavier fertilizer applications, but severe snowbreakage was also increased. Thus, net production tended to be greatest with the addition of 200 pounds of nitrogen. Indications are that heavier application rates will have a longer lasting beneficial effect.

INTRODUCTION

A nitrogen-fertilizer trial in a 35-year-old, site V Douglas-fir plantation on Wind River Experimental Forest in southwestern Washington clearly illustrates substantial growth response. This interim report assesses the influence of fertilizer during the first 4 years following treatment in terms of basal area growth per acre, snowbreakage, diameter growth, height growth, and cone production. Findings of this study are consistent with those reported by others for low-site conditions^{1/} and add to an accumulating knowledge of what can be accomplished through forest fertilization.

^{1/} Gessel, S. P., et al. The growth behavior of Douglas-fir with nitrogenous fertilizer in western Washington. Univ. Wash. Coll. Forest. Res. Bull. 1. 1965.

The plantation is located at the east edge of the Yacolt Burn in an area that was repeatedly swept by wildfire, the last in 1927. At the start of the study, the trees had sparse, chlorotic foliage and were growing very slowly. In a nearby part of the same plantation, an admixture of red alder had significantly increased nitrogen content of the soil and of Douglas-fir foliage, and increased the rate of Douglas-fir growth.^{2/} This led to initiation of the study reported here.

THE STUDY

Treatment

In April 1964, ammonium nitrate was applied to 0.1-acre circular plots at rates of 0, 200, 400, and 600 pounds of nitrogen per acre. Each treatment was applied to three plots, in a completely random design (fig. 1).

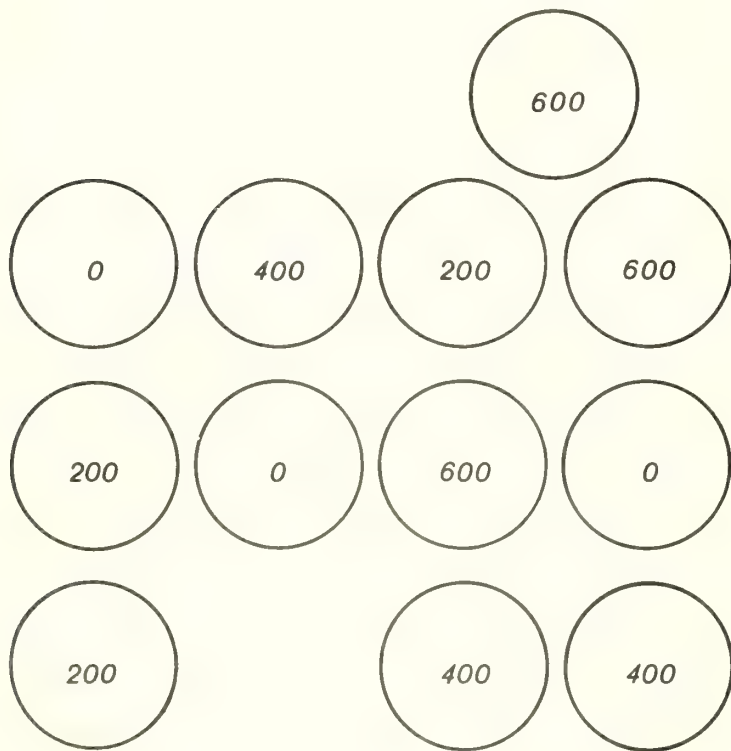


Figure 1.--Arrangement of plots, identified by pounds of nitrogen fertilizer applied.

^{2/} Tarrant, Robert F. Stand development and soil fertility in a Douglas-fir—red alder plantation. Forest Sci. 7:238-246. 1961.

Pretreatment Condition

Trees had been planted in 1930 at an average spacing of 8 by 8 feet, but actual spacing was quite erratic. Thus, although trees tended to be in rows, there was no clearcut configuration to the spatial arrangement. Basal area on these plots averaged 101 square feet per acre in trees averaging 5.6 inches d.b.h. and 45 feet tall. Site index averaged 87 and ranged from 79 to 96 (height at age 100). Basal area per acre on most of these plots was below normal by McArdle's yield tables,^{3/} most likely as the result of incomplete occupancy of the area by trees. Expressed as a percent of normal for the indicated site index of each plot, stocking after the 1963 growing season (and before winter mortality) ranged from 73 to 106 percent of full stocking, averaging 87 percent.

Measurements

Diameters of all trees on the central 0.05-acre portion of each plot were measured to the nearest 0.1 inch in April 1964 and in the fall of 1965, 1966, and 1967. Heights of at least seven of these trees, distributed equally over the d.b.h. range, were measured concurrently. In 1967, heights on a total of 14 trees were measured on each plot, and height to the 1963 terminal was measured on all of these which had not been included in the initial measurement.

RESULTS AND DISCUSSION

Basal Area Increment Per Acre

Averaged for each treatment, 4-year gross basal area increment was 68 to 120 percent greater in fertilized stands than in unfertilized stands. Growth in all fertilized stands was significantly better than that in unfertilized stands. However, because of considerable within-treatment variation, growth did not differ significantly among the three fertilizer treatments.

A look at annual increment during this 4-year period gives a little more complete picture of the effect of the different intensities of fertilizer on gross increment (table 1). Unfortunately, we did not make a measurement after the first growing season, so we must use the average for the first 2 years.

Aside from treatment effects, annual gross basal area growth varied considerably during this 4-year period. For example, on the untreated plots, growth in 1966 was nearly twice as great as the average annual growth in 1964-65, whereas growth in 1967 was only about half of that in 1964-65, or one-quarter of the 1966 growth. With such

^{3/} McArdle, Richard E., et al. The yield of Douglas-fir in the Pacific Northwest. U.S. Dep. Agr. Tech. Bull. 201. 1930 (rev. 1961).

Table 1.--*Annual gross basal area increment by treatment and year (average of three observations)*

Treatment ^{1/}	1964-65 ^{2/}	1966	1967	4-year total
----- <u>Square feet</u> -----				
0	3.2	6.2	1.6	14.2
200	5.0	9.0	4.9	23.9
400	6.0	11.3	7.0	30.3
600	5.6	11.8	8.2	31.2

^{1/} Pounds of nitrogen per acre.

^{2/} Average for 2 years.

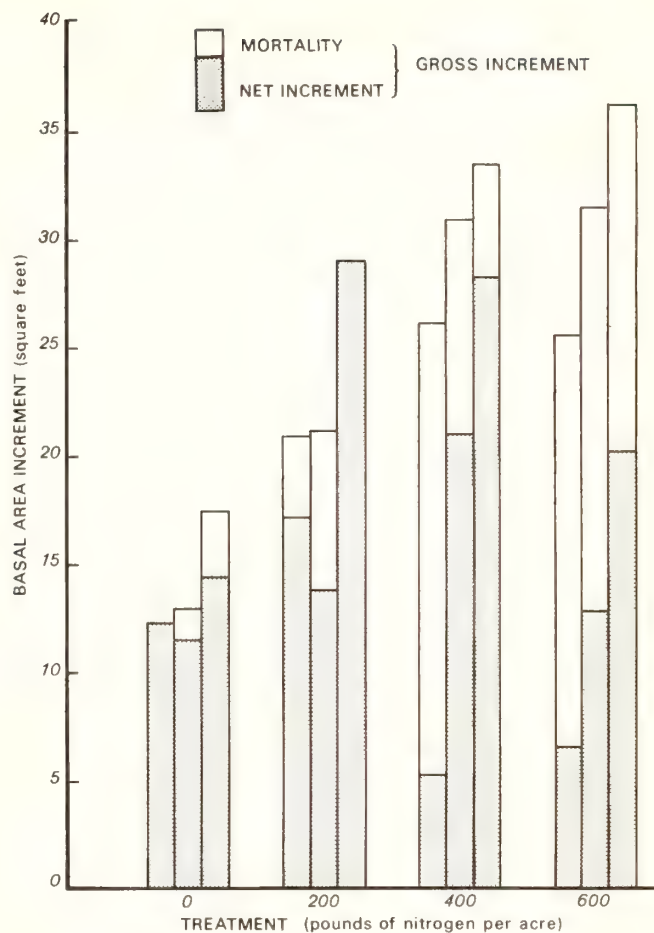
wide differences in growth rate from one year to another, it is quite possible that relative effects of fertilizer treatments were different than if annual growth had been more uniform.

The treatment-year interaction for this first 4 years was not quite significant, but there are indications that a trend may be developing. Growth in the third year, 1966, averaged by treatments, varied from 180 to 211 percent of the average for the first 2 years and showed no clear relationship to treatment. On the other hand, growth in the fourth year varied from 50 to 146 percent of the average for the first 2 years, and showed a very clear trend of increasing relative growth with increasing amounts of fertilizer. This changing trend may be associated primarily with poor growing conditions in the fourth year,^{4/} as exemplified by the unfertilized plots. Conversely, it may indicate that, whereas all fertilizer treatments tested had virtually the same initial effect on gross increment, the longevity of the effect increases with increasing intensity of fertilizer application.

Substantial mortality was associated with the heavier fertilizer intensities. Thus, net basal area increment over the 4-year period tended to be greatest in stands receiving 200 pounds of nitrogen per acre (fig. 2).

^{4/} Growing conditions refer to both environment and physiological condition of trees.

Figure 2.--Effect of fertilizer on 4-year basal area increment (three observations per treatment), 1964-67.



Snowbreakage

Total number of trees suffering severe storm damage since the time of fertilizer application differed significantly among treatments, with the moderately and heavily fertilized stands incurring about three times as much damage as the unfertilized and lightly fertilized stands.

Breakage during the first winter following treatment was generally quite severe but was also quite erratic and did not differ significantly among treatments. Similar damage occurred the winter preceding treatment. Breakage during the second winter, on the other hand, did differ significantly among treatments and increased as fertilizer intensity increased.

Thus, moderate and heavy fertilizer application apparently increased amount of storm breakage, with much of the impact being delayed until the second winter following treatment. Kreutzer^{5/} similarly

^{5/} Kreutzer, K. Ernährungszustand und Volumenzuwachs von Kiefernbeständen neuer Düngungsversuche in Bayern. Forstwissenschaftliches Centralblatt 86:28-53. 1967.

observed that, as the weight of needles increased with improvement in nitrogen nutrition, the danger of snowbreakage simultaneously became greater.

Virtually all of this snowbreakage was very severe. Most trees which have survived thus far have most of their crowns broken out and stand a very slim chance of recovery, but many linger on. Fertilizer has apparently somewhat hastened their death (table 2).

Table 2.--*Number of trees damaged since time of treatment
(sum of three plots per treatment)*

Treatment ^{1/}	Damaged trees			Percent dead
	Total	Dead	Live	
0	7	2	5	29
200	10	5	5	50
400	29	20	9	69
600	32	21	11	66

^{1/} Pounds of nitrogen per acre.

Only 6 percent of the damaged trees were among the largest 200 trees per acre. Thirty-one percent were among the second largest 200 trees per acre. In most cases, the damaged trees would probably not have amounted to much anyway, although most currently had ample growing space. Also, the loss of these trees generally did not offer much release to leave trees.

D.b.h. Growth

We are interested in the effect of fertilizer on growth of the individual trees as well as growth per acre. Basal area growth per acre may give a misleading impression of the effect of various fertilizer intensities on growth of the individual trees because the severe storm damage on moderately and heavily fertilized plots took substantial areas temporarily out of production. For this reason, d.b.h. growth of undamaged surviving trees was analyzed separately.

Plottings of 4-year d.b.h. growth over starting d.b.h. showed the relationship to be linear. Regressions fitted to the data show that, in all treatments, growth was virtually proportional to tree size; an 8-inch tree grew twice as much as a 4-inch tree (fig. 3). On the

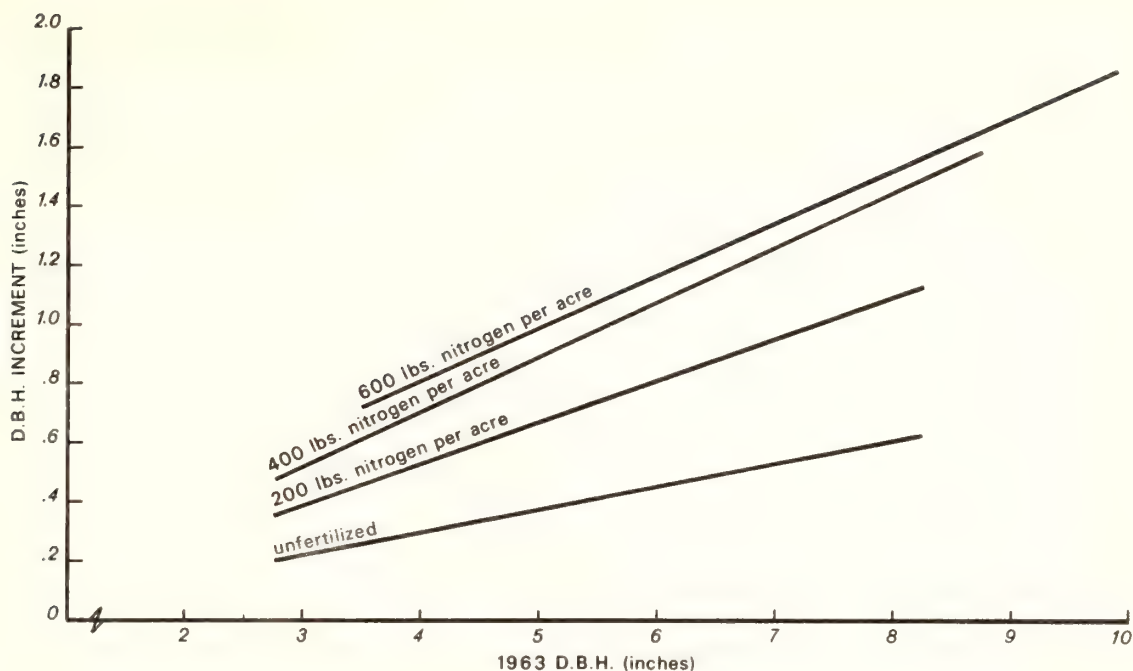


Figure 3.--Effect of fertilizer on 4-year d.b.h. increment, 1964-67.

average, d.b.h. growth of trees in fertilized stands was 79 to 160 percent greater than in unfertilized stands. Growth was significantly better in all fertilized stands than in unfertilized, and growth in moderately and heavily fertilized stands was significantly better than that in lightly fertilized stands. Growth on plots receiving 600 pounds nitrogen per acre was not significantly better than that on plots receiving 400 pounds nitrogen. Differences in growth among treatments tend to increase with time, but the interaction between year and treatment is not currently significant.

Most of the increase in growth rate is probably attributable directly to fertilization. However, since there was considerable natural thinning (mortality) in the moderately and heavily fertilized stands, a few trees were released and likely grew more than had this storm damage not occurred.

Height Growth and Change in Site Index

Average height growth of the nine tallest trees measured per plot (approximate dominant and codominant component) differed significantly between fertilized and unfertilized stands, but not among fertilizer treatments. Average growth in fertilized stands was 62 percent greater than that in the unfertilized stand--8.1 versus 5.0 feet.

As a result of this increased height growth, apparent site quality was greatly improved by fertilization but did not differ significantly among fertilizer treatments. Based on 1963 height and 1964-67 height growth of the nine tallest trees measured per plot, average improvement in site index on fertilized plots was 55--from site index 88+ to 144- (height at age 100). The corresponding improvement on unfertilized plots was 6--from 84 to 90.

Cone Production

Cone production was nil on all plots in all years except 1966. In that year, cone production was clearly better in the fertilized stands than in the unfertilized. There were no clear differences among the fertilizer treatments. Cones were produced only on trees larger than about 7 inches d.b.h. (i.e., about the largest 30 percent of the trees).

CONCLUSIONS

Application of 200 to 600 pounds of nitrogen per acre substantially improved both d.b.h. and height increment, and thus growth per acre (table 3). Height increment was significantly better in fertilized

Table 3.--*Effect of fertilizer on 4-year basal area, d.b.h., and height increment, 1964-67*

Treatment ^{1/}	Gross basal area increment	D.b.h. increment	Height increment
	<u>Square feet</u>	<u>Inches</u>	<u>Feet</u>
0	14.2	0.42	5.0
200	23.9	.73	7.7
400	30.3 *	1.06	8.7 *
600	31.2	1.10	8.0

^{1/} Pounds of nitrogen per acre.

* Values connected by vertical line are not significantly different.

stands than in unfertilized, but did not differ significantly among fertilizer treatments. D.b.h. increment, on the other hand, also differed significantly between stands receiving 200 and 400 pounds of nitrogen per acre, but not between those receiving 400 and 600 pounds.

Thus far, little has been gained by applying as much as 600 pounds of nitrogen per acre. The relative advantages of 200 versus 400 pounds per acre are not so clear. Whereas trees grew substantially more with the latter, incidence of storm damage, a common occurrence in this area, was increased. Thus, at least on a short-term basis, increase in net production per acre tended to be greatest with 200 pounds per acre. However, there are indications that this trend may change over time, and the study will be continued to determine such changes.

Pacific
North
West Forest and Range Experiment Station
Forest Service **RESEARCH NOTE**

PNW-87

September 1968



AN OPERATIONAL TEST
OF A NATURAL-SHAPED LOGGING BALLOON

By

Virgil W. Binkley, *Research Forester*

and

Ward W. Carson, *Mechanical Engineer*





Figure 1.--Raven Industries, Inc., natural-shaped balloon.

ABSTRACT

A three-month test was performed to evaluate a natural-shaped balloon under logging conditions, near Reedsport, Oregon. Data were collected on the balloon's availability, maintenance records, handling requirements, and yarding performance. The balloon was found to be stable and operable in winds up to 25 m.p.h. and capable of surviving storms when properly bedded down.

INTRODUCTION

One of the major concerns in balloon logging is the stability of the balloon. Exposed as it is to a variety of weather conditions--particularly to frequently varying winds in mountainous regions--a balloon must remain relatively stable in flight. To determine the flight characteristics of a "natural-shaped" balloon when used in logging, Raven Industries, Inc., Sioux Falls, S.D., and Bohemia Lumber Co., Culp Creek, Oreg., ran tests during the summer and early fall of 1967 on the Siuslaw National Forest near the central Oregon coast.

The natural-shaped balloon (fig. 1) has several characteristics that distinguish it from other types. Its name is derived from the fact that a lifting gas naturally assumes this shape under the weight of the fabric containing it. The fabric of the fully inflated balloon is stressed uniformly,¹ which allows use of a material of uniform thickness in construction. This minimizes the weight of material required to contain a given amount of gas, and by this means, the design achieves the highest static lift efficiency of any balloon shape.

The natural-shaped balloon achieves its high static efficiency and simplicity in design and construction at the expense of airfoil characteristics; thus, any relative air movement produces dynamic drag without dynamic lift.

Prior to the tests, there was no known documentation of experience on large natural-shaped balloons operating in a tethered mode. Common experience indicated that small tethered balloons have a tendency to oscillate excessively in wind. Military and industrial experience showed a high degree of stability for large natural-shaped free balloons in varying wind conditions because the relative wind is zero, but the effect of adding a tether cable could not be clearly predicted. Nor could data from wind tunnel tests be used to forecast success in logging, since the use of wind tunnel data in a stability analysis of tethered balloons is presently not a clearly defined science.

Because of the unique characteristics of the natural-shaped balloon, its performance in logging could only be evaluated by a field test. Consequently, the Pacific Northwest Forest and Range Experiment Station contracted with Raven Industries, Inc., to report on the results of the test. Under the terms of the contract, Raven Industries was to provide detailed test data covering 160 operating hours.

The test was completed in October 1967 under the direction of Terry Wright, project engineer with Raven Industries, and in cooperation with Bohemia Lumber Co.

The following information has been developed from data taken during this 160-hour test period.

¹Smalley, Justin H. Balloon design data in gore lengths. Air Force Cambridge Research Laboratories, AFCRL-65-447, 63 pp., illus. 1965.

DESCRIPTION OF TEST

Site Layout

The logging site was on the north shore of the Umpqua River, approximately 10 miles east of Reedsport, Oreg. The location was the U.S.D.A. Forest Service Brandy Bar sale, units 1 and 2 (fig. 2). The site included 92 acres of clearcutting plus 7 acres of road right-of-way outside the cutting units.

The elevation ranged from near sea level to over 800 feet. The slopes averaged 55-60 percent and were fairly constant.

Timber Types and Volumes

The sale contained 2,900,000 board feet of 80-year-old Douglas-fir with miscellaneous associated species. The stand averaged 21 inches at breast height; the stand had a cruise defect of 18 percent and averaged 29,300 board feet per acre.²

Log Transport System

Both units were logged downhill by balloon. Yarding distances varied from approximately 200 to 1,500 feet. From the landing, the logs were swung by tractor to the north shore of the Umpqua River. They were dumped into the river and rafted across to the Brandy Bar landing on the south shore of the Umpqua River, where they were loaded onto trucks and hauled to the mill.

Equipment Description

The following equipment was used in the yarding operation:

	<u>Quantity</u>
Natural-shaped balloon	1
Balloon transfer vehicle	1
Helium storage trailer	1
Yarder	1

The natural-shaped balloon had a diameter of 82 feet and held 250,000 cubic feet of helium. It weighed 3,000 pounds and had a net static lift of approximately 11,500 pounds. The fabric was of a dacron base with elastomer coating on both sides. The load was suspended from the envelope with a modified tangent harness system. A light fabric was attached to the suspension system, which formed an external skirt-ballonet. It was pressurized by ram air acting through one-way valves around the lower circumference of the skirt.

The rigging was similar to that in conventional high-lead yarding, except that the balloon was tethered 500 feet above the butt rigging to provide direct lift to the logs.

The tagline was put together in segments so that its length could be quickly changed to suit the requirements of individual turns, thus reducing block changes. The actual length varied from 150 feet up to 300 feet.

The balloon was moved from the bed-down area to the yarder by the balloon transfer vehicle--a double drum winch mounted on a modified M-4 tank chassis. The bottom of the tank hull was filled with scrap steel to provide additional weight.

A helium storage trailer was kept at the site to supply replacement gas to the balloon.

The yarder was a prototype interlocking unit, manufactured specially for balloon logging by Washington Iron Works, Seattle, Wash. It was mounted on an M-6 tank chassis for easy mobility and was powered by a 700-horsepower diesel engine driving through a 4-speed transmission. In fourth gear, the yarder was capable of a line speed of 2,200 feet per minute. However, for this operation, the

²Brandy Bar Timber Sale Prospectus. August 1965. Siuslaw National Forest, Corvallis, Oreg.

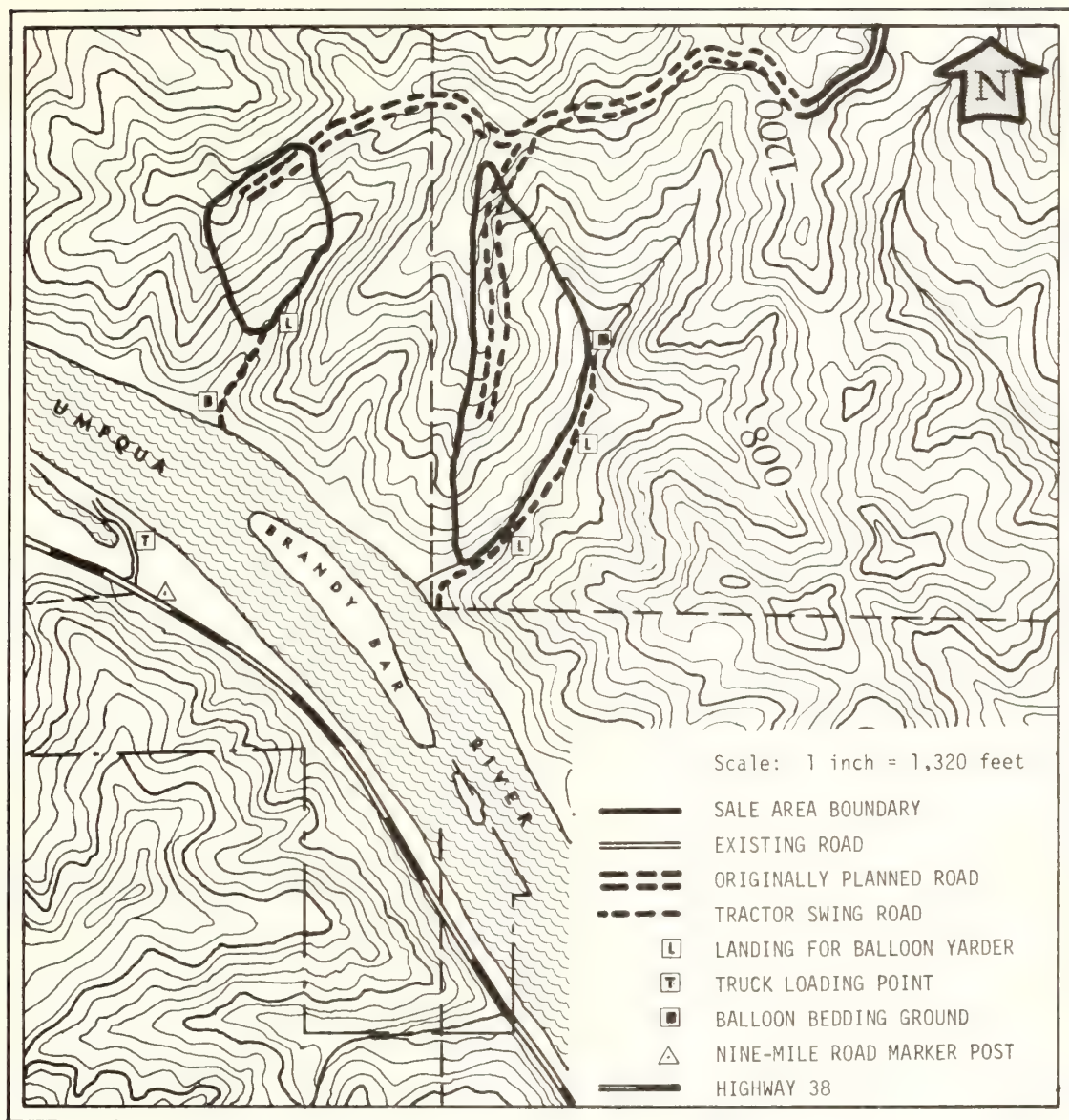


Figure 2.--Timber sale map, Brandy Bar; Smith River Ranger District, Siuslaw National Forest, Secs. 5 and 6, T. 22 S., R. 10 W., Willamette Meridian

yarder was run in third gear, which gave a maximum line speed of 1,700 feet per minute.

Logging Crew

The logging crew consisted of regular employees of Bohemia Lumber Co., some of whom had previous experience on balloon logging operations. The normal crew size was five men--two choker setters, one chaser, one hook tender, and one yarder engineer. They were under the general direction of Frank Mosher, balloon logging superintendent of Bohemia Lumber Co.

Test Procedure

The data were collected by Raven Industries personnel under the test plan prepared by the Pacific Northwest Forest and Range Experiment Station's Forest Engineering Research Project in Seattle. The test plan provided for collecting the following data: equipment performance, effects of weather, daily summary, and cycle time analysis.

TEST RESULTS

Equipment Performance

At the beginning of these tests, the major question was whether the balloon would be sufficiently stable in wind to permit safe log transport.

During operation, the balloon was exposed to winds estimated at 20-25 m.p.h. In these winds, the layover angle was approximately 15° to 20°. The balloon oscillated gently and slowly, having approximately a 35-second period which did not interfere with the logging operation or the control of the balloon.

This test demonstrated that the balloon can be used safely in wind conditions normally expected near the Oregon coast

at this time of year. Also, an unusual windstorm on October 2 proved the balloon's ability to survive storm conditions.

Effects of Weather

Adverse weather occurred during August, September, and October. During the test period, extreme forest fire hazard forced closure for 11 full days and 27 half days. This contrasts sharply with the average of only 1.5 full days and 2 half days for this zone during 1956-66.³ During these closures, the balloon was on the bedding ground.

The windstorm of Monday, October 2, severely tested the wind survival capabilities of the balloon. The storm was described in newspaper reports as the worst in 5 years, and its intensity was exceeded in history only by the Columbus Day storm of 1962. The Weather Bureau officially recorded gusts of 58 m.p.h. at Eugene and 78 m.p.h. at Portland. An unofficial Coast Guard report gave winds of 85 m.p.h. on the coast near Reedsport, approximately 12 miles from the balloon beddown site. Other unofficial reports recounted gusts of 100 to 120 m.p.h. along the coast between North Bend and Newport. The wind caused extensive damage in the entire Oregon coast area.

The balloon was bedded down during the storm in a well-sheltered area to avoid the direct force of the wind. A competent observer estimated the balloon was actually exposed to 50- to 60- m.p.h. winds.

A system of eight tie-down lines (these are visible in the photograph of figure 1) and the main load fitting bedded down the balloon, with approximately one-third of the total lift carried on the load fitting

³Oregon State Forestry Department. Annual Close Down Reports. Salem, Ore. 1956-67.

and the rest on the tie-down lines. With this tie-down arrangement, the balloon successfully resisted the storm, and a careful inspection the next day did not disclose any significant wind damage to the balloon.

Daily Summary

The daily summary (table 1) shows the production and time distribution of the balloon logging system during the test. Total elapsed time from start to finish was 433.7 hours. During this time, the balloon was available for yarding 88 percent of the time. The balloon was not available when maintenance was required during normal working hours (5.4 percent) and when winds were too severe to allow operation (6.6 percent).

Fire weather delays (28.0 percent) and yarder delays (11.4 percent) together represented 39.4 percent of total elapsed test time. Neither of these can be interpreted as representative of normal logging conditions.

Cycle Time Analysis

During the tests, a detailed time breakdown of 105 individual turns was made. The results are shown below:

	Percent of turn time
Haulback	30
Set chokers	19
Inhaul and landing	39
Unhook chokers	12
	100

The following definitions were used in recording these times:

Haulback.--Elapsed time from the instant the chokers leave the landing until the balloon is positioned over the logs and the choker setter grabs the chokers.

Set chokers.--Elapsed time from the instant the choker setter grabs the chokers until the command to lift the log is given.

Inhaul and landing.--Elapsed time from the command to lift the log until the log stops moving in the landing. Includes any time for lifting and resetting the log in the landing if necessary.

Unhook chokers.--Elapsed time from drop of the log to rest on the landing until start of the balloon on the haul-back of the next cycle.

Conclusion

This test provided an interesting and productive addition to the developing "state of the art" of balloon logging. With the unusual conditions of fire weather closure, realistic cost figures were not obtainable on these first flight tests of a natural-shaped logging balloon. However, Bohemia Lumber Co. is confident of economical future production.

Indications are that a natural-shaped logging balloon may be considered operational in winds under 25 m.p.h. and capable of surviving storms when properly bedded down in a sheltered location.

Table 1.--Daily summary of balloon logging test, July-October 1967

Date	Total time	Yarding time	Fire closure	Rigging	Balloon handling	Yarder delay	Miscellaneous delay	Wind delay	Balloon maintenance	Balloon availability (total time less wind and balloon maintenance)	Turns	Logs	
Hours											Number		
July	26	4.7	3.9			0.3				4.7	18	53	
	27	8.0	6.7		0.2	1.2				8.0	41	114	
	28	10.0	6.9		2.0		1.1			10.0	56	176	
	31	8.0	2.2		1.5	.5	3.8			8.0	20	57	
Aug.	1	8.0	6.3	.5		.2	1.0			8.0	46	110	
	2	8.0				8.0				8.0			
	3	8.0				8.0				8.0			
	4	8.0	4.5	2.1		1.4				8.0	34	78	
	7	8.5	7.0			.5	.3	0.7		7.8	51	102	
	8	8.0	5.5	2.4	.1					8.0	46	110	
	9	8.0	6.9	.8	.2					8.0	56	136	
	10	8.0	7.0	1.0						8.0	62	173	
	11	8.0	6.8	1.0	.2					8.0	57	147	
	14	8.0	1.8		2.2				4.0	4.0	12	37	
	15	8.0	6.5		1.0		.5			8.0	54	162	
	16	8.0	2.5			5.5				8.0	26	80	
	17	8.0				8.0				8.0			
	18	8.0				8.0				8.0			
	21	8.0		8.0						8.0			
	22	8.0		8.0						8.0			
	23	8.0		8.0						8.0			
	24	8.0		8.0						8.0			
	25	8.0		8.0						8.0			
	28	8.0				8.0				8.0			
	29	8.5	7.0		1.5					8.5	44	136	
	30	8.0		8.0						8.0			
Sept.	31	8.0		8.0						8.0			
	1	8.0		8.0						8.0			
	4	8.0		8.0						8.0			
	5	8.0		8.0						8.0			
	6	8.0		8.0						8.0			
	7	8.0		8.0						8.0			
	8	8.0		8.0						8.0			
	11	8.0	6.0		2.0					8.0	57	157	
	12	8.0	7.5	.5						8.0	40	90	
	13	8.0	5.6	2.2	.2					8.0	38	119	
	14	8.0						8.0					
	15	8.0		8.0						8.0			
	18	9.0	7.3	.8	.9					9.0	66	215	
	19	8.5	3.5	.6	1.0		.4		3.4	5.1	23	84	
	20	8.0							8.0				
	21	8.0	7.7				.3			8.0	70	225	
	22	8.0	6.6	1.1			.3			8.0	53	142	
	25	8.0	6.5	1.2			.3			8.0	58	174	
	26	8.0	4.2					3.8		4.2	26	77	
	27	8.0	2.2				5.8			8.0	20	53	
	28	8.0	1.5	.3			6.2			8.0	12	31	
Oct.	29	8.5	5.5		3.0					8.5	43	112	
	2	8.0						8.0					
	3	8.0						8.0					
	4	8.0							8.0				
	5	8.0	5.7	1.3	1.0					8.0	43	132	
	6	8.0	5.1	1.0	1.0		.9			8.0	35	102	
	9	8.0	6.3	.5	1.2					8.0	56	182	
Total		433.7	162.7	121.5	8.8	18.5	49.8	20.9	28.5	23.4	381.8	1,263	3,566
Percentage of total		100	37.5	28.0	2.0	4.3	11.4	4.8	6.6	5.4	88.0		

Pacific
North
West Forest and Range Experiment Station
Forest Service **RESEARCH NOTE**

PNW-88

September 1968

NATURAL FILTERING OF SUSPENDED SOIL BY A STREAM AT LOW FLOW

by

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Associate Hydrologist

Abstract

During road construction, soil that is added to a stream by tractors crossing during low flow is temporarily "filtered" out before it travels far. Five-gallon samples were taken at 150, 300, 600, and 1,200 feet downstream from a road crossing, with sodium fluorescein dye used as a tracer. Suspended particle concentration was reduced from 1,055 p.p.m. at 150 feet below the road to 108 p.p.m. at 1,200 feet. The "filtering" action is a combination of settling of larger particles and dilution of sediment-laden water. This filtration is temporary and deposited soil will tend to be flushed downstream during high flows and may cause channel erosion or other damage.

Introduction

During forest road construction, quantities of soil may be introduced into streams by tractors crossing the stream before culverts or bridges are installed. On Bull Run Experimental Watersheds in the Cascade Range of northwest Oregon, a significant quantity of soil was put into the stream by tractors but was not observed at the streamflow measuring station one-half mile below the road construction. To trace the soil movement, we measured the suspended solids, added by a single tractor crossing, at intervals to 1,200 feet downstream. The stream had a low-gradient, rocky channel with many pools, and flow was less than one-half cubic foot per second--a low-streamflow situation in August 1964.



Methods

Sediment-laden water was followed visually until it reached the first sampling point 150 feet downstream from the road crossing. There, a 5-gallon sample was taken by successively filling a pint sample bottle at a small overfall. At this time, sodium fluorescein solution (a brilliant yellow-green dye) was added to the stream to identify the same general water mass at sampling points further downstream.^{1/} Additional 5-gallon samples were taken when the dye reached sampling points located 300, 600, and 1,200 feet downstream from the road construction. The actual flow distance of the water meandering around the rocks was 1-1/2 to 2 times greater than the length of channel. Three hours elapsed while water flowed from the road crossing to the last sampling point.

Samples were taken to the laboratory and sieved through a 0.05-millimeter (300-mesh) screen to separate the sand-size particles. One-liter subsamples of the sieved solution were used for determining the silt and clay fraction by the pipette method.^{2/}

Results

The particle-size analysis data plotted in figure 1 show a tenfold reduction in total suspended-solids concentration during flow through 1,050 feet of stream channel. As expected, sand dropped out quickly; its concentration fell from 80 to 2-1/2 parts per million (p.p.m.) in the first 150 feet. The silt concentration steadily declined from 600 to 3 p.p.m. over the whole 1,050-foot distance. The apparent initial increase in clay concentration between 150 and 300 feet is attributed to sampling error. Clay concentration decreased from about 400 to 100 p.p.m. at the last station.

Several reasons exist for the marked reduction in suspended solids with increasing distance from point of input. Gravitational force continuously causes particle deposition. Deposition increases when flow slows in pools and side eddies. Mosses growing on submerged rocks reduce flow velocity and encourage deposition. Moss also presents a large surface area to collect particles.

A third explanation for the decrease in concentration is the dilution effect of water in pools. At every pool some mixing of dirty

^{1/} Wright, Robert R., and Collings, Michael R. Application of fluorescent tracing techniques to hydrologic studies. J. Amer. Water Works Ass. 56(6): 748-754. 1964.

^{2/} Kilmer, Victor J., and Alexander, Lyle T. Methods of making mechanical analyses of soils. Soil Sci. 68: 15-24. 1949.

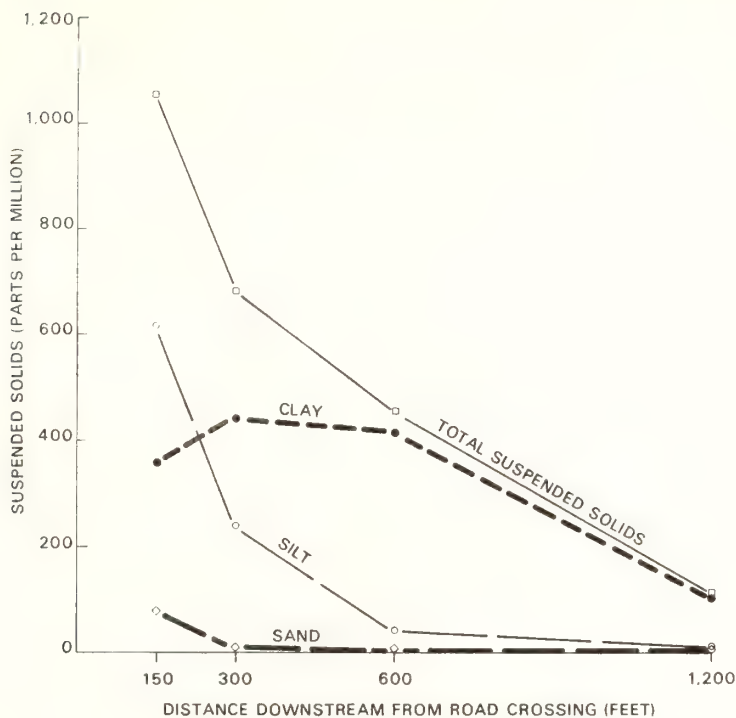


Figure 1.--*Suspended-solids concentration at several distances from study road crossing. Bull Run Experimental Watershed No. 1.*

and clear water occurs, and water leaves the pool with a lower suspended solids concentration than when it entered. Dilution increases the volume of turbid water and extends the length of the affected water mass as it moves downstream.

Discussion

Suspended particles lower water quality, and efforts should be made to keep tractors out of streams above a campground or water supply inlet. However, during low-flow conditions the natural "filtering" action of the stream tends to reduce particle concentrations within a relatively short distance, and careful operations may be carried out without seriously impairing the water supply. If particles are introduced into higher, more turbulent flows, particles will move further downstream before being deposited, but concentrations may still be reduced because the diluting volume is greater.

Undisturbed stream channels in natural forest are relatively stable. Soil added from any source disturbs this stability and will be flushed from the channel by subsequent high flows. Flushing of deposits may cause accelerated bank or channel cutting. The relatively rapid clearing of water below a work area may lead to an underestimate of the potential damage from introduced soil. Even intermittent additions of soil to the stream or occasional stream channel disturbances should be regarded as harmful. Thus, every effort should be made during road construction to install culverts without disturbing the channel and to install culverts or bridges as early as possible to provide dry crossings for mechanical equipment.

Acknowledgments

The study was part of the cooperative research program between the City of Portland Bureau of Water Works and the Pacific Northwest Forest and Range Experiment Station. Dr. C. T. Dyrness, Soil Scientist at Forestry Sciences Laboratory, Corvallis, Oregon, assisted with the concentration determinations.

* * * *

PNW-89

September 1968

POTENTIAL DAMAGE TO FOREST TREE SEED DURING PROCESSING,
PROTECTIVE TREATMENT, AND DISSEMINATION^{1/}

by

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Abstract

Seed is susceptible to damage each time it is handled. Damage may be inflicted during various steps in processing, treatment with chemicals, or dissemination by seeding devices. There is evidence that seed damage is cumulative. Thus, each new bump or treatment may bring the seed closer to death. Some present practices cause damage to seed, but the contribution to impaired germination from each possible source of damage is not known. Research is needed to develop the best possible methods for processing, treating, and disseminating valuable tree seed.

Dissemination of seed by most western forest trees is aided by a seed wing which also serves as a parachute to insure the seed a soft landing. This is Nature's way--painless seed extraction; floating, gliding seed dissemination. Forests have regenerated this way for

^{1/} From a speech presented at the Tree Seed and Reforestation Seminar for Southwest Oregon, sponsored jointly by the Siskiyou Chapter, Society of American Foresters, and Southern Oregon College, October 19-20, 1967, Ashland, Oreg.

centuries. Then along comes the forester. Nature's way is too slow for him. So he picks cones--frequently before they are ripe--roughly extracts the seeds, and forcibly removes Mother Nature's seed parachute. Later, he coats the seeds with toxic chemicals and blasts them out over the forest through seeding devices which are anything but gentle.

Seed is susceptible to damage each time it is handled. Because seed damage is cumulative, each new bump brings the seed closer to death, whether the bump comes from processing or dissemination, and whether the seedcoat is broken or unbroken. Protective chemicals, which may enter through the cracks or breaks or be imbibed by the intact seedcoat, must also be considered potential contributors to poor seed performance.

First, let's look at data from Dr. George Allen's studies^{2/} in British Columbia on physical damage to seed--how it may be caused and how it affects germination. Then, we'll consider information from a study on helicopter seeding devices conducted by the Pacific Northwest Region, Forest Service, U.S. Department of Agriculture. Next, we will take up chemicals and coatings, drawing information from the literature and from a small laboratory test made at the Pacific Northwest Forest and Range Experiment Station. Finally, we will dwell upon the inter-related effects of physical and chemical damage. Looking back on it all, I believe you will be struck by the inadequacy of our knowledge and the need for more research on seed.

Physical Damage to Seed

Some of Dr. Allen's tests show how commercial processing of cones and seeds may reduce germination percent of Douglas-fir. In one study, replicated samples were taken (1) from the hopper before processing started, (2) from different places in the seed bin under the tumbler, (3) after different lengths of time in the dewinger, and (4) following passage through the cleaner (fig. 1). Seeds taken from the first quarter, second quarter, and last half of the seed collection bin were designated grade 1, 2, 3, respectively. These grades represent increasing lengths of time seed was in the tumbler. The respective grades were processed through the dewinger and the cleaner. Seed which left the hopper with a germination capacity of 94.5 percent came out of the cleaner averaging 63.3 percent. Seed which fell from the tumbler early suffered least, even if subjected afterward to 30 minutes in the dewinger. Even so, the smallest difference from start to finish exceeded 12 percent. This is too great a loss to accept if avoidable.

^{2/} Allen, G. S. Factors affecting the viability and germination behavior of coniferous seed. Forest. Chron. 34: 266-298, illus. 1958.

FULL DRY CONES

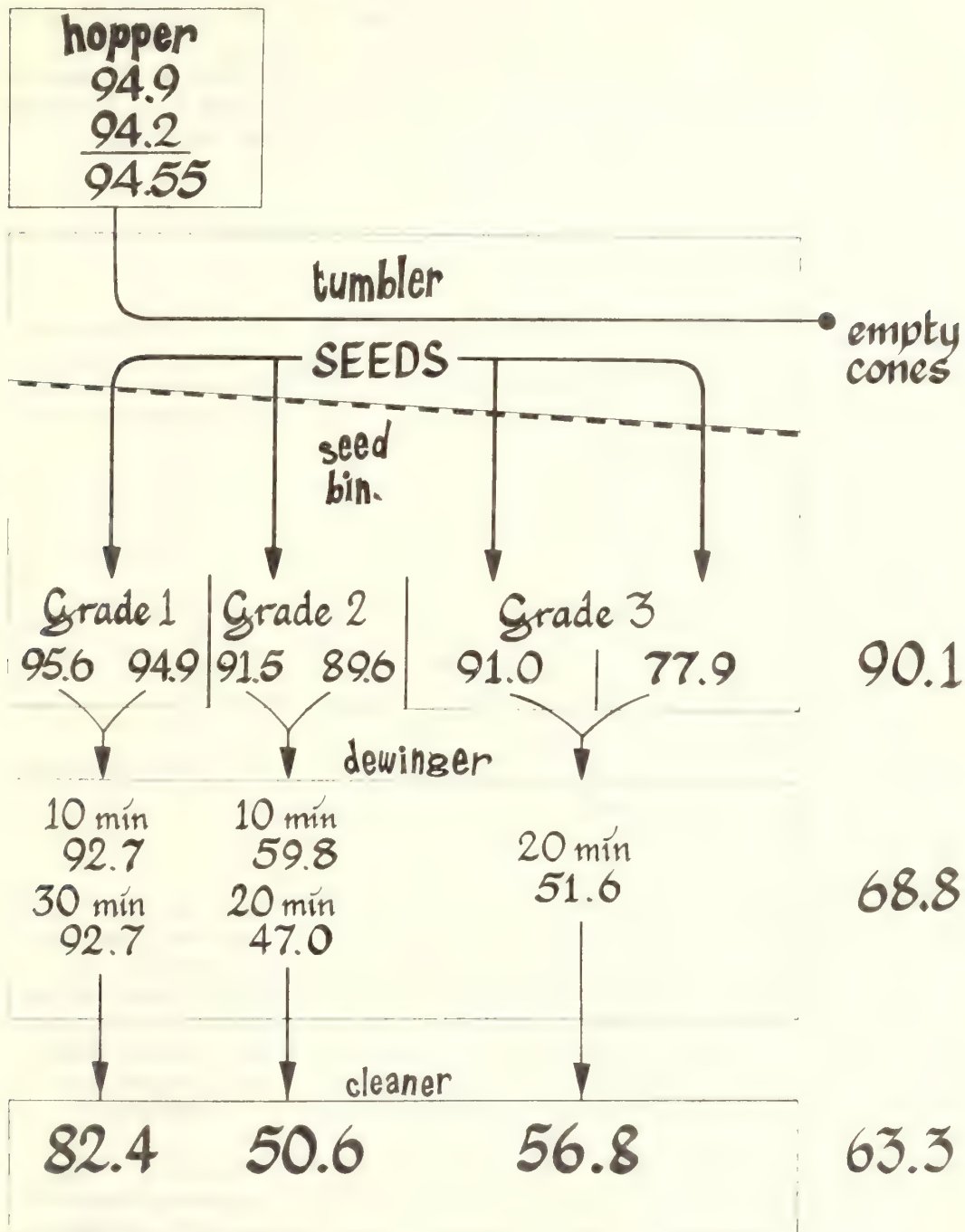


Figure 1.--Average germination capacity (percent) of Douglas-fir seed lot 5621 at three stages of processing. (Data from reference given in text footnote 2.)

In maltreatment experiments, Allen determined that a weight of 2.1 grams dropped on a Douglas-fir seed from a height of 16.5 centimeters-- a 34.65 gram-centimeter (g.-cm.) force--was just sufficient to crack the seedcoat. If seeds whose germination capacity averaged 80.0 percent were subjected individually to a shock sufficient to crack the seedcoat, average germination capacity was reduced to 1.2 percent (table 1).

Table 1.--Average germination capacity of stratified Douglas-fir seed after various maltreatments^{1/}

Treatment	Germination capacity
	----- Percent -----
Control--commercially processed seed	80.0
Cracked seed only--sorted from commercial lot	12.5
Sound seed:	
Cracked by 34.65 g.-cm. impact	1.2
Given impact of 23.10 g.-cm., 1 time	51.5
Given impact of 11.55 g.-cm., 1 time	81.2
Given impact of 11.55 g.-cm., 3 times	17.2
Given impact of 11.55 g.-cm., 5 times	7.2

^{1/} Data from Allen 1958; see text footnote 2.

An impact of two-thirds this amount, 23.10 g.-cm., reduced germination capacity to 51.5 percent, but one-third as much, 11.55 g.-cm., had no adverse effect on germination. However, when applied repeatedly, the effect is cumulative: three 11.55 g.-cm. blows reduced germination to 17.2 percent; five blows reduced germination to 7.2 percent. In other words, seed which is bumped and squeezed in processing but still viable afterward may very well receive small bumps in later handling which prove fatal, though these bumps may be insignificant by themselves.

Dissemination by helicopter may give seed those additional small bumps. The metering device squeezes and crushes some seed, as can be seen when equipment is cleaned. Impacts, occurring when seed is slung out over a wide swath, may even exceed Allen's critical 34.65 g.-cm. force. Just falling on a rock, log, or stump without benefit of parachute provides considerable shock. Added to the damage caused by processing, any one of these events might be sufficient to kill an already weakened seed.

Recently, the Forest Service's Pacific Northwest Region conducted tests to determine to what degree helicopter seed dissemination devices were injurious to seed. In ground trials, replicate samples of four species were put through five helicopter disseminators and caught in suspended parachutes. On the average, germination was not reduced, but some inconsistencies in results are thought provoking (table 2).

Table 2.--Average germination of endrin-treated seed before and after dissemination by five different helicopters

Species	Before dissemination	After dissemination by helicopter					Average
		1	2	3	4	5	
----- Percent ^{1/} -----							
Douglas-fir	53.0	53.5	65.5	45.0	58.0	54.0	55.2
White fir	20.0	21.0	17.0	16.0	21.0	20.0	19.0
Ponderosa pine	77.0	71.5	72.0	71.0	64.5	72.5	70.3
Lodgepole pine	85.0	87.0	90.0	90.0	85.0	90.5	88.5
All	58.9	58.2	61.1	55.5	57.1	59.2	58.2

^{1/} Difference between means must exceed 14.7 percent for significance at 5-percent probability level.

Only Douglas-fir germination was affected unequally by dissemination equipment on different helicopters. Germination was significantly lower after seed passed through equipment on helicopter 3 than after passing through equipment on helicopter 2. Though we can see that Douglas-fir germination percent after dissemination ranged from 45.0 to 65.5 percent, the 55.2-percent average is obviously not significantly different from the 53-percent average germination before dissemination. Surely, lack of statistical significance is unimportant here; if there is a choice, equipment which produced 65.5 percent germination will be used. The most important point is that the effect of dissemination equipment varied among helicopters. Why it varied has not been determined.

Seed Protection With Chemicals

Chemical coatings may harm seed germination in two ways: (1) they contain one or more ingredients which may be toxic to seed, and (2) they form layers on the seedcoat that may slow assimilation or be impermeable to the water and oxygen essential for germination. Partially weakened seeds, which would ordinarily produce seedlings, may not survive with such mechanical handicaps. Yet, coatings must be resistant to weathering and, therefore, be sparingly soluble in water to be effective.

Several treatments used for protecting seed from rodents have proven somewhat detrimental to germination. Dick et al.^{3/} found that addition of Arasan 75 to a mixture containing endrin, Methocel-Rhoplex, and aluminum flake did not improve Douglas-fir seedling establishment and adversely affected seed viability in laboratory tests by 8 to 10 percent. Substitution of Dow Latex 512-R for Methocel-Rhoplex did not change results. Shea^{4/} found that Arasan 75 decreased field germination of Douglas-fir and he recommended that use of Arasan 75 in the protective mixture be discontinued. Allen^{5/} reported that Douglas-fir seed, stratified after treatment with tetramine, lost nearly 30 percent in germination capacity compared with untreated seed. Germination of shortleaf pine seed was adequate when treated after stratification with an endrin-anthraquinone-Latex 512-R mixture and stored at two temperatures for up to 30 days.^{6/} Seidel found that this protective treatment reduced germination slightly but felt it was not enough to offset benefits of protection.

In the helicopter seed dissemination study, treatment with endrin reduced germination of Douglas-fir seed from 69 to 53 percent, white fir from 35 to 20 percent, ponderosa pine from 81 to 77 percent, and lodgepole pine from 88 to 85 percent. This finding was somewhat tenuous since the study was designed to test dissemination equipment, not endrin treatment, and there were no replicated tests made for comparing germination before and after treatment. However, consistently lower germination after treatment is a warning signal.

Another interesting point is that after dissemination, germination

^{3/} Dick, James, Finnis, J. M., Hunt, Lee O., and Kverno, Nelson B. Treatment of Douglas-fir seed to reduce loss to rodents. J. Forest. 56: 660-661, illus. 1958.

^{4/} Shea, Keith R. Field survival of thiram-treated Douglas-fir seed. Weyerhaeuser Co. Forest. Res. Note 38, 8 pp. 1961.

^{5/} See footnote 2.

^{6/} Seidel, Kenneth W. Germination of treated shortleaf pine seed. U.S.D.A. Forest Serv. Res. Pap. CS-5, 12 pp., illus. 1963.

of treated Douglas-fir seed increased as much as 12.5 percent, from 53 to 65.5 (table 2). Individual replicates of other species also showed greater germination after dissemination than before. It is not clear whether this represents random variation or an equipment effect. Possibly, protective seedcoatings were cracked or worn off during dissemination, allowing easier penetration of oxygen and water.

We have also tested some candidate stickers, using calcium carbonate to substitute for the usual powdered ingredients. Most stickers tested, including some in use at present, did not adversely affect germination of seed from the two 1959 collections (fig. 2). However, there was one

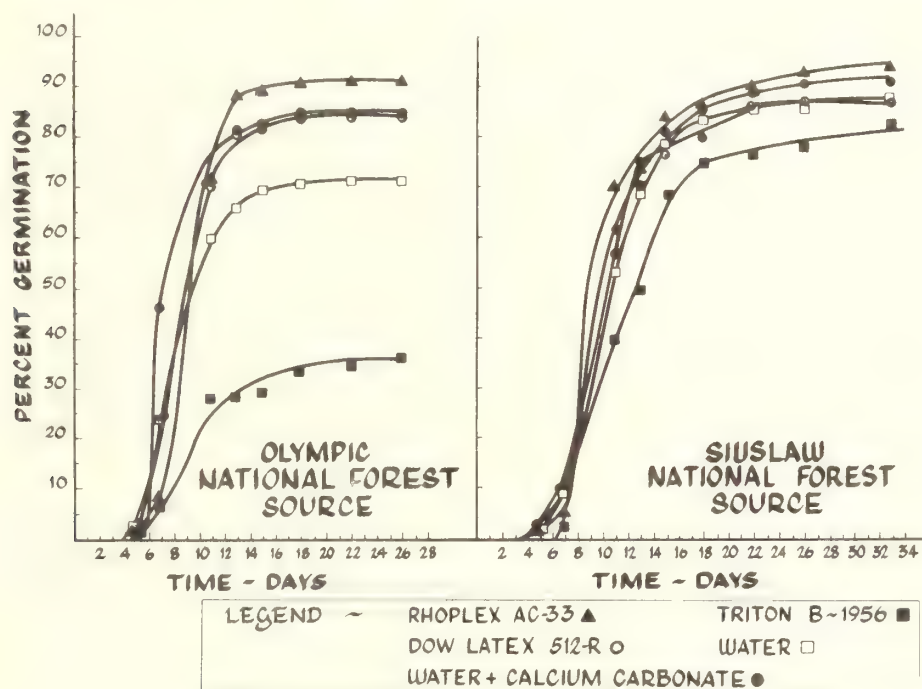


Figure 2.--Germination of Douglas-fir seed stratified for 3 weeks after sticker treatment.

potentially bad actor in the group--Triton B-1956 apparently hindered germination. An unnumbered Velsicol sticker, which did not adversely affect the 1959 seed, reduced germination of an older lot from 48 to 38 percent. This means that the effect of stickers may vary with age of the seed. Other stickers tested but not shown in figure 2 were Plyac, Gen-Flo Latex 671, Velsicol W617, and Velsicol WX888.

Though we now have good indications that several stickers may be safe when used on Douglas-fir seed, we do not know how they will act when mixed with various seed-protecting chemicals. Research on protective coatings for seed must be stepped up sooner or later.

The types of damage we have considered are obviously interrelated. First, the processing treatment bruises, squeezes, cracks, and breaks seedcoats and seeds. Chemicals are then added which may enter the cracks and breaks and make life harder for the damaged seeds. Some seeds, which survived despite cracks and breaks, may now succumb to the toxic chemical. The added coating may also restrict passage of vital water and oxygen. Next, the seed is disseminated by helicopter, being run through a grinder called a metering device and blasted forcibly down curved or angled chutes or tubes. Bumps and squeezes received here are added to those received in processing. Seeds, lucky enough to escape processing relatively unscathed, may receive fatal blows during dissemination.

The contribution to impaired germination from each source of damage is not known. It would be interesting, for instance, to know if chemical coatings affect seeds with intact seedcoats. Possibly, most impaired germination due to fungicides or rodenticides is visited upon seed with damaged coats. No comprehensive investigations of seed protectant effects on damaged and undamaged seed have been conducted.

We need effective chemicals that are not toxic to seed or people. We need processing methods that are gentler with seed. We need dissemination devices that do not bump, squeeze, and buffet seed. It may sound strange to hear a researcher imploring seed users to get more research done. It is not so strange. The impetus must come from the users.

As seed collection methods improve and seed orchards and production areas enjoy greater use, acreage of seeded forest land will increase. Seed used to regenerate these acres will be expensive seed. We must be prepared to make the best possible use of it.

Pacific
North
West Forest and Range Experiment Station
Forest Service **RESEARCH NOTE**

PNW-90

September 1966

BUD CHARACTERISTICS OF PONDEROSA PINE RELATED TO POTENTIAL
DAMAGE BY THE EUROPEAN PINE SHOOT MOTH

by

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ABSTRACT

Bud characteristics of young ponderosa pine in open stands were studied as a possible basis for determining susceptibility or resistance of these stands to the European pine shoot moth. A survey of numbers and sizes of buds on branch apices showed three different bud patterns in eastern Oregon and Washington, and a fourth pattern in the Willamette Valley of Oregon. A study of resin canal development at two plots in northeastern Oregon showed that terminal buds had more and larger longitudinal resin canals than did lateral buds in the same cluster, and that elongation of resin canals occurred more rapidly in terminal buds. In July 1964, resin canal development in ponderosa pine in northeastern Oregon was much more advanced than it was on Scotch pine in the shoot moth-infested Puget Sound area. Bud number and size and probable differences in resin production between terminal and lateral buds should be tested in natural pine stands as indicators of resistance to the European pine shoot moth.

The European pine shoot moth, *Rhyacionia buoliana* (Schiff.), poses a potentially serious threat to western pine forests. It now infests pine ornamentals, nursery stock, and Christmas tree plantations in much of western Washington and in a few localities in Oregon and British

^{1/} Teacher in Biological Sciences, The Dalles High School, at The Dalles, Oreg., employed as Biological Aid during these studies.

Columbia. Research is needed to determine whether or not this insect will become a serious pest in young forest stands of ponderosa (*Pinus ponderosa*) and lodgepole (*P. contorta*) pines.

Growth characteristics of host pines apparently affect the amount of shoot moth damage. Rapid height growth of red pine (*Pinus resinosa*) has been associated with reduced susceptibility to shoot moth damage (Heikkinen and Miller 1960), and number and size of leader buds influence the impact of larval feeding (Miller 1967). Survival of larvae on Scotch pine (*Pinus sylvestris*) was related to the amount of resin encountered during the initial attack on the buds; differential development of the insect and the resin canals was suggested as a factor in larval survival, with warm summers favoring larval attack before resin canals were well developed (Harris 1960). Harris noted that resin flow of lodgepole pine did not inhibit shoot moth attack and suggested that some resins were more readily emulsified than others by the larval vomitus. In studies of *Rhyacionia* spp. on southern pines, Yates (1966) considered differential host injury to be a result of effects of oleo-resin on feeding larvae.

"Inherent differences in susceptibility are found between pine species and are suspected at a subspecific level" (Holst and Heimbürger 1955). Susceptibility is difficult to evaluate under planted conditions. Holst and Heimbürger (1955) state that variation in susceptibility seems to be caused by (a) possible variation in seed source and (b) degree of matching of the planting site to the site requirements of the planted materials, especially in respect to climate. Possibilities for breeding for resistance, in pines of the *Lariciones* and *Insignes* groups, for Ontario conditions were described by Holst (1963).

Whether species characteristics of western hard pines, particularly ponderosa, would permit survival and population buildup of European pine shoot moth and result in economic damage in the pine region remains to be shown. An economic evaluation by Flora (1965), based on analogy with Lake States conditions, assumes that severe damage to ponderosa pine will occur on poor sites and some damage on medium sites, except in those areas where low winter temperatures kill or limit the spread of the shoot moth. However, the concept of site, in the sense of the mensurationist, may be misleading; the key need seems to be recognition of specific site factors affecting establishment and multiplication of the shoot moth in young stands. The hazard is chiefly to young trees, and morphological indicators of tree condition are sorely needed. Surprisingly, two recent bibliographies on ponderosa pine (Cummings 1967; Axelton 1967) indicate a minimum effort in this direction.

In areas of the Pacific Northwest, we studied bud characteristics of ponderosa pine in 1964 and 1965 to obtain information related to possible susceptibility of this host to the shoot moth. The findings

will aid in formulating studies in natural pine stands for evaluating the biological threat to ponderosa pine. Similar studies on lodgepole pine are also planned.

OBJECTIVES

The broad purpose of the study was to determine the extent of morphological differences between apical bud clusters in ponderosa pines growing in different localities and between buds in the same cluster on individual trees. A standard condition imposed was that pines should be approximately even aged and growing in openings without an immediate overstory.

Presence and characteristics of lateral buds were a key to differences between localities and between buds in the same cluster. Because of the possible significance of resin flow as a factor in increasing tree resistance, differences in resin canal development between buds were of particular interest.

Therefore, specific objectives were to determine:

1. Numbers and sizes of buds per apical cluster on young ponderosa pines in various eastern Oregon and Washington localities.
2. Characteristics of resin canal development in ponderosa pine buds in one area in the pine region.

In addition, timing of shoot moth attack in the Puget Sound area, in relation to resin canal development, was briefly explored.

METHODS

The longitudinal dimension of a bud has been described both as length (Mergen et al. 1960) and height (Harris 1960). In this paper, "bud length" is used to describe external measurement of the bud, including the scale covering, and "bud height" to describe internal measurement of the growing bud, with the scale covering removed. Resin canal development is described in reference to bud height, hence the term "resin canal height" is used.

Bud Complement

At 10 locations known to have young open-grown pines, observations were made after bud elongation appeared completed. Bud measurements

were obtained at two locations in northeast Oregon during August 18-19, ^{2/} 1964, and at eight other locations during August 30 - September 2, 1965. Five pines per location, in a general height class of 7 to 12 feet, were sampled; apical bud clusters were examined on two branches from each of the upper, middle, and lower third of the crowns. Numbers of terminal and lateral buds in each cluster were recorded for each branch, and length and maximum width of each bud were measured. In addition, total height and crown length of each tree were recorded.

Measurements from the five trees were averaged by crown third to determine: (1) average length and width of terminal as compared with lateral buds to the nearest 0.5 mm. (millimeter), and (2) average number of lateral buds per 10 terminal buds. Averages for the different locations were compared for evidence of different bud complement patterns. In addition, the range in which 80 percent of all measurements for a single pattern occurred was used to show the probability that the patterns were different.

Observations were made at two points in the Willamette Valley of Oregon, to deduce differences in bud complement possibly attributable to climatic factors. In 1965, a group of trees, planted as 2-0 stock in fall 1958 at a study site in Portland, was sampled; seedlings were obtained from a central Oregon forest nursery. The results stimulated a search for native ponderosa pine in the general vicinity, and in fall of 1967, records on bud size and number were obtained for trees near Turner, about 45 miles to the south of Portland.

Bud and Resin Canal Development

Studies were conducted in 1964 on two plots in northeast Oregon, near Union; one plot was at an elevation of 4,100 feet and the other at 5,100 feet. Temperature and humidity were recorded at the 4,100-foot plot. Observations began at the 4,100-foot plot on July 2 and at the 5,100-foot plot on July 8.

Bud structure and growth.--The external characteristics of ponderosa pine buds were noted in order to develop methods for sectioning buds. Internal characteristics studied were limited to longitudinal resin canals and pith; histogenesis in the bud axes of *Pinus lambertiana* and *P. ponderosa* has been described by Sacher (1954). Seasonal growth characteristics were deduced from surplus bud material collected at the 4,100-foot plot and held in alcohol.

^{2/} Locations sampled in 1964 were Bennett Peak and Dooley Mountain (Wallowa-Whitman National Forest); in 1965, Bear Springs (Mount Hood National Forest), Pole Creek Road (Deschutes National Forest), Brush Creek Road (Ochoco National Forest), Dixie Pass and Deer Creek Road (Malheur National Forest), Bull Prairie Guard Station (Umatilla National Forest), Monument Road (Goldendale, Wash.) and Naches Ranger Station (Snoqualmie National Forest).

Resin canal development.--Number, height, and diameter of longitudinal resin canals were compared between terminal and lateral buds in apical clusters. Terminal buds were sectioned weekly at both plots beginning July 8; regular examination of lateral buds began on July 29, when internal elongation was sufficient to define sectioning points. Approximate elongation of resin canals in lateral buds prior to July 29 was later determined by sectioning surplus material held in alcohol. Weekly observations continued until September 9, when bud growth appeared ended.

Two apical bud clusters were removed from branches in the middle crown of each of five pines. Bud clusters were placed in 70 percent alcohol for a week to clear the resin canal openings. Buds were then sectioned with a razor blade at two-thirds height and one-third height after the bud sheath was removed. If no resin canal development was visible at two-thirds height, a section was made at one-half height. For each section, number and diameter of resin canals and diameter of the pith, inside the circlet of resin canals, were recorded. Figure 1 shows the appearance of a terminal and one lateral bud sectioned at one-third bud height.



Figure 1.--Terminal bud and associated lateral bud of ponderosa pine sectioned at one-third bud height; 4,100-foot plot, August 5, 1964. (X12)

Table 1.--Possible bud complement patterns on young ponderosa pine, based on ranges in average bud size and average number of lateral buds between different geographical locations

Pattern	Number of locations	Crown height	Terminal buds		Lateral buds		Number per cluster
			Average length	Average width	Average length	Average width	
-----Millimeters-----							
1 (small buds)	2	Upper	8.4 (8.0-8.8)	4.5 (4.1-5.0)	1/ 6.2	1/ 3.4	0.2 (0 -0.4)
		Middle	6.6 (6.4-6.8)	4.0 (3.5-4.5)	3.7 (2.5-5.0)	2.5 (2.0-3.0)	1/1
		Lower	5.4 (4.5-6.3)	3.4 (2.8-4.0)	--	--	0
2	6	Upper	13.2 (11.6-16.6)	5.4 (5.0-5.9)	8.0 (6.6-9.0)	3.1 (2.7-3.4)	.6 (0.3-1.0)
		Middle	10.0 (8.4-12.7)	4.7 (4.2-5.2)	6.8 (3.9-10.0)	2.7 (2.1-3.0)	.4 (0.1-0.9)
		Lower	7.0 (6.2-8.9)	3.7 (3.4-4.2)	4.5 (3.7-4.1)	1.7 (2.2-3.0)	.2 (0 -0.4)
3 (large buds)	2	Upper	21.3 (18.9-23.7)	6.6 (6.3-7.0)	13.2 (10.5-15.9)	3.7 (3.4-4.1)	1.7 (1.4-2.1)
		Middle	15.0 (12.5-17.5)	5.3 (4.7-6.0)	9.0 (7.2-10.7)	3.0 (2.8-3.1)	1.4 (0.9-2.0)
		Lower	9.9 (9.4-10.4)	3.7 (3.6-3.9)	5.4 (5.3-5.5)	2.0 (1.9-2.1)	.5 (0.2-0.8)
4 (very large buds)	2/ 2	Upper	29.4 (25.8-33.1)	8.1 (7.1-9.1)	16.4 (13.1-19.8)	4.4 (3.8-5.1)	3.0 (2.8-3.2)
		Middle	22.0 (19.9-24.1)	6.9 (6.4-7.4)	12.0 (9.7-14.3)	3.8 (3.6-4.1)	2.8 (2.6-3.1)
		Lower	15.6 (14.8-16.3)	5.3 (5.2-5.4)	8.6 (7.7-9.6)	3.2 (3.1-3.4)	1.7 (1.7-1.8)

1/ Lateral buds were present at only one of two locations.

2/ In the Willamette Valley.

Bud and Resin Canal Development

Bud structure and growth.--The terminal bud is stout and covered with several layers of scales. During elongation, its external diameter is constant up to about half-bud height, then decreases, tapering sharply on the upper third. At first, the sheath of scales extends 3 to 5 mm. beyond the bud apex, leaving a hollow. By the end of the growing season, the bud apex fills the hollow, the upper part of the bud thickens, and the sheath tip becomes sharply pointed. Larger lateral buds are similar in shape to the terminal bud and point sharply away from it. Undersized and immature lateral buds are usually compressed against the terminal bud.

At the 4,100-foot plot in northeast Oregon, terminal buds in the middle-crown third were 8 to 12 mm. long during early July and 15 to 20 mm. long in mid-August when their height growth appeared ended. Lateral buds began to form in early July, and completed height growth late in August. Examples of bud development at 3-week intervals, starting July 8, are shown in figure 2.

At the 5,100-foot plot, terminal buds were also 8 to 12 mm. long in early July but were slightly larger than those at the 4,100-foot plot by the end of August; lateral buds lagged behind terminal buds in development. Approximate growth rate of buds at the 4,100-foot plot is shown in figure 3. Growth rate at the 5,100-foot plot is believed to be similar.

Resin canal development.--Terminal buds had more and larger resin canals and showed more rapid height growth of resin canals, than did lateral buds.

Cross sections of buds showed two general types of longitudinal resin canals. "Primary" resin canals, arranged in a circlet, were visible early in bud growth. Later, "secondary" canals--apparently, the branch canals described by Sacher (1954)--appeared. These usually were outside the circlet of primary canals.

Terminal buds showed a circlet of usually 13 primary resin canals, whereas lateral buds at 4,100 feet showed usually eight primary resin canals and those at 5,100 feet usually nine (table 2). Number of primary canals per bud was the same for both the one-third and two-thirds bud heights, until branch canals developed. Then some small variation occurred in counts where one or more branch canals developed within the ring of primary canals and was recorded as a primary canal.

In terminal buds, primary resin canals were at one-half bud height on July 2, based on observations only at 4,100 feet. These resin canals were apparent at two-thirds bud height at both elevations on July 8, but were not measurable until July 15. In lateral buds, primary resin canals reached half-bud height on July 15; they were not measurable at two-thirds bud height until July 29, 2 weeks later than in terminal buds.



A



B



C



D

Figure 2.--Examples of ponderosa pine bud development at 4,100 feet in northeastern Oregon on the following dates: A, July 8; B, July 29; C, August 19; D, September 9. (X2.7)

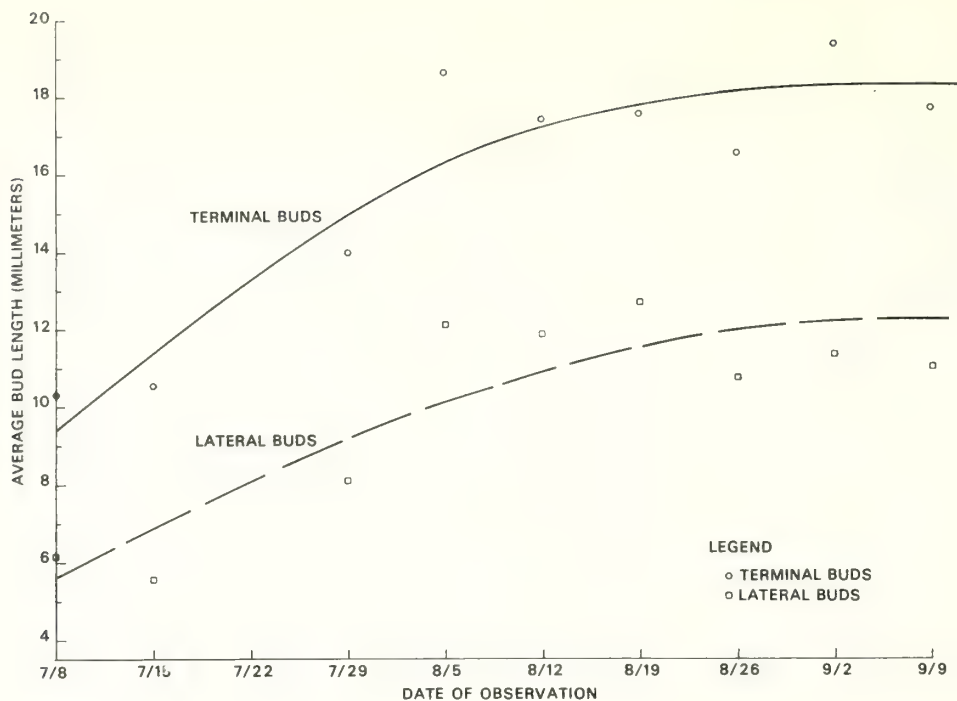


Figure 3.--Ponderosa pine bud growth at 4,100-foot elevation in northeastern Oregon.

Table 2.--Average number of primary resin canals in ponderosa pine buds at one-third bud height, two elevations

		4,100 feet		5,100 feet	
Date		Terminal buds	Lateral buds	Terminal buds	Lateral buds
July	2	12.8	--	--	--
	8	13.0	--	13.8	--
	15	13.4	--	13.3	--
	22	13.0	--	13.0	--
	29	12.9	8.0	13.1	8.0
Aug.	5	13.0	8.0	(1/)	(1/)
	12	15.2	9.4	12.6	10.1
	19	12.8	8.0	13.3	9.1
	26	13.0	8.6	12.7	9.4
Sept.	2	12.8	8.1	13.1	8.7
	9	12.8	9.8	13.9	11.5
Average		13.3	8.6	13.2	9.5

^{1/} Heavy rainstorm cut off access to this plot on date of scheduled examination.

Branch canals were first noted at one-third bud height on August 12, in both terminal and lateral buds and at both plots. In terminal buds, these canals were common at two-thirds bud height on August 26 and readily identified. In lateral buds, they also occurred at two-thirds bud height on this date but in small number. At this position in the bud, they tended to appear within the circlet of primary canals, and were usually recorded as additional primary canals.

Branch canals were about twice as numerous in terminal buds as in lateral buds on a given collection date, ranging as high as 20 in terminal buds and 12 in lateral buds. Because these arise by branching from primary canals, the difference in numbers is due to the larger number of primary canals in terminal buds. Within the sample of terminal and lateral buds examined on a given collection date at each plot, variation in number of branch canals was considerable. Variation between dates was also large, no doubt due to inconsistency in selecting sectioning points as well as variation in bud development.

Average diameter of primary resin canals was generally greater in terminal buds than in lateral buds (table 3). An odd finding was that, after July 29, average diameter of primary resin canals at one-third bud height decreased. This was thought to be an artifact resulting from either: (1) selection of large buds early in the period of observation, or (2) gradual shifting upward of sectioning points as the internal shoot apex elongated. When collection date was ignored, regression analysis showed a significant linear relationship between diameter of primary resin canals and pith diameter in both terminal and lateral buds at both plots. (In three regressions, the linear effect was significant at $p = 0.01$; the regression for lateral buds at 5,100 feet showed a cubical as well as a linear effect at $p = 0.05$.) Regression lines for terminal buds at the two elevations were similar; those for lateral buds at the two elevations were also similar (fig. 4).

If we can assume pith diameter is indicative of size of bud, the regression shows that larger resin canals are found in larger buds, regardless of time of year. Thus, the measurements were consistent and apparently in line with results by Harris (1960) showing actual resin production to be proportional to bud size.

Average diameter of branch canals was less than that of primary canals in the same bud at the same height. No real comparison could be made between terminal and lateral buds; most branch canals were small--0.05 mm. or less in diameter. A few, however, were of the same size and in approximately the same position as the primary canals.

Table 3.--Average diameters of pith and primary resin canals in ponderosa pine buds at one-third bud height and at two elevations; July 2 to September 9, 1964

Date	Elevation, 4,100 feet				Elevation, 5,100 feet				
	Terminal buds		Lateral buds		Terminal buds		Lateral buds		
	: Resin :		: Resin :		: Resin :		: Resin :		
	Pith	canals	Pith	canals	Pith	canals	Pith	canals	
----- <u>Millimeters</u> -----									
July	2	1.80	0.10	--	--	--	--	--	--
	8	1.85	.13	--	--	2.37	0.15	--	--
	15	2.60	.19	--	--	2.72	.20	--	--
	22	2.70	.19	--	--	2.59	.15	--	--
	29	2.89	.15	0.93	0.13	2.82	.18	1.05	0.13
Aug.	5	2.41	.11	.88	.09	(1/)	(1/)	(1/)	(1/)
	12	1.73	.09	.70	.08	2.13	.11	.88	.09
	19	1.41	.10	.64	.10	2.72	.14	.88	.11
	26	2.04	.13	.80	.09	2.41	.16	.75	.11
Sept.	2	1.90	.10	.81	.09	1.96	.11	.69	.09
	9	1.47	.07	.74	.07	1.58	.07	.83	.07

1/ Observations not made because road was washed out by rainstorm.

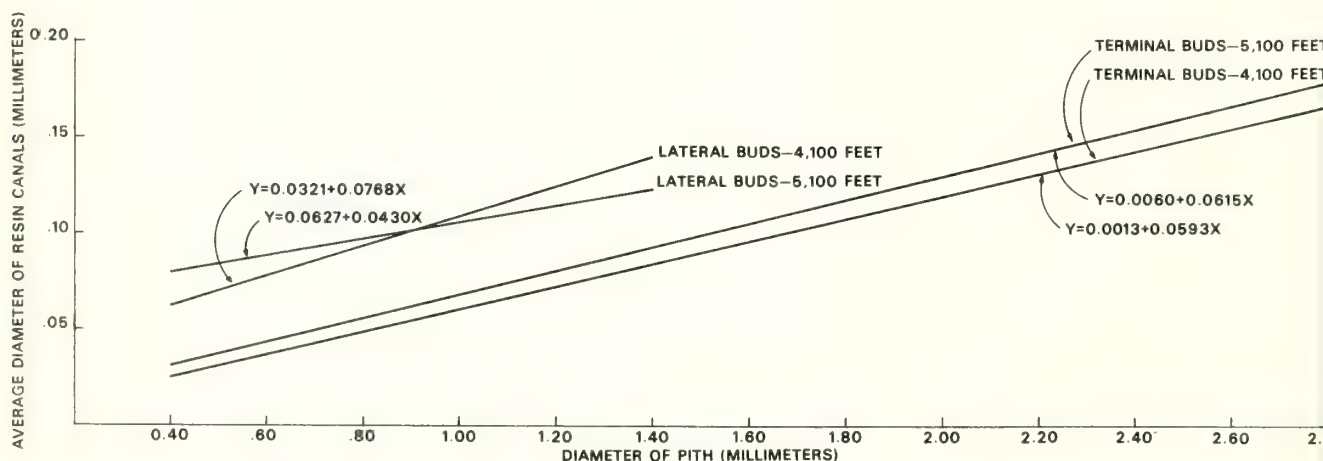


Figure 4.--Relationship between diameter of resin canals and diameter of pith in ponderosa pine buds, at one-third bud height, two elevations.

Weather conditions.--Records obtained during the study period indicated a more or less typical summer for this area, so that bud growth as recorded was probably normal. July and August were generally dry months, with mostly hot days and cool nights. A violent rainstorm on August 5, however, washed out several roads in the woods. Until late August, daily high temperatures exceeded 90° F. 2 or 3 days in each 7-day period, with the exception of one cool period from July 30 to August 5. Daily low temperatures ranged from 32° to 54°, but were mostly between 38° and 48°. Starting on August 13, a cooling trend was evident in the evening temperatures, and starting on August 26 a sharp downward trend in diurnal temperatures commenced. Freezing temperatures occurred on 2 of 6 nights during the final week of records, September 3-9, and snow fell on September 9 at the 5,100-foot plot.

Resin Canal Development and Time of Shoot Moth Attack

Sampling of Scotch pine in the Puget Sound area showed that larvae were attacking buds at an early stage of resin canal development. Primary resin canals had reached one-half bud height in only 60 percent of the terminal buds and 40 percent of the lateral buds. At this height all canals were less than 0.05-mm. diameter. At one-third bud height, resin canals in 10 terminal buds averaged 0.10-mm. diameter; canals in 13 terminal buds were less than 0.05-mm. diameter. All resin canals at one-third height in lateral buds were less than 0.05-mm. diameter.

Comparable resin canal development on ponderosa pine in the north-eastern Oregon plots in 1964 existed during the period July 2 to 8, as already described, some 23 to 29 days earlier than with Scotch pine in the Puget Sound area. Thus, at least part of the growth period presumably favorable to shoot moth attack would normally occur early in the season in east-side ponderosa pine stands, despite the late initiation of seasonal growth.

DISCUSSION

Results of the limited survey of bud complements on ponderosa pine suggest two different hypotheses. One is that young ponderosa pine stands can be classified on the basis of size of terminal buds and number of lateral buds per apical cluster, to indicate probable area differences in tree susceptibility to the shoot moth.

An alternative hypothesis is that size of terminal buds and number of lateral buds are directly related to an environmental factor, such as available moisture. Local variation in bud complements would then be considerable, and assessment of hazard would need to be based on recognizable local conditions rather than on relatively large areas.

The bearing of bud size and bud numbers on potential damage by the shoot moth is difficult to anticipate. Potential damage can be evaluated from the likelihood of success of initial attack or on the impact of subsequent feeding. Using the latter criterion, Miller (1967) concluded that less damage occurs with greater numbers of buds. However, in our potential problem with naturally growing pines, success of initial attack as influenced by bud size and number may be the proper criterion.

Bud size is probably an important factor in success of initial attack. In our studies, terminal buds showed a much greater capacity to produce resin than did lateral buds. The potential is in part influenced by bud size, which is directly related to resin canal area as indicated by Harris (1960). In addition, terminal buds have a greater number of resin canals than do lateral buds, as shown by our studies. Thus, larger terminal buds should be relatively resistant to shoot moth attack. Indeed, Brookes and Brown (1936) suggested that larvae attack lateral buds in autumn because terminal buds are excessively resinous.

Number of lateral buds has several ramifications. With regard to initial attack, it would appear that chances of successful attack by an individual larva would increase with a greater number of lateral buds. Further, more larvae could become established within a bud cluster. This line of reasoning appears substantiated by the large shoot moth populations found on ornamental pines with many lateral buds in the Puget Sound area.

The frequent absence of lateral buds from branch tips in natural stands of ponderosa pine in Oregon and Washington may constitute a strong resistance factor; larvae would be forced to compete for acceptable buds. Small numbers of larvae surviving to the spring-feeding period might still cause serious damage to these pines by migrating to the upper crown and attacking the leader. Actual numbers of larvae surviving up to this time and the probability of successful migration upward would be key aspects in estimating damage.

Timing of larval attack on lateral buds, in relation to development of resin canals, would also be an important factor in survival. Contrary to Wareing's assumption (in Harris 1960), development of lateral buds lags behind that of terminal buds, probably increasing their susceptibility to successful attack. However, development of lateral buds in the pine region is rapid in comparison with other areas, because growth is compressed into a short growing season. Whether phenology in the pine region will pose an obstacle to the shoot moth in adapting to ponderosa pine remains to be seen.

RESEARCH NEEDED

This study has provided some research leads for determining the hazard posed by the European pine shoot moth to natural stands, particularly of ponderosa pine. Quarantine sanctions are being obtained for studying the insect's behavior in relation to tree host characteristics in the pine region. Tests related to host characteristics should be conducted so as to determine:

1. Relative success of larval attack on lateral and terminal buds at different stages of resin canal development.
2. Relative success of larval attack on bud clusters with (a) no lateral buds, (b) one lateral bud, and (c) two or more lateral buds.
3. Value of large terminal buds and abundant lateral buds as an indicator of available moisture in pine stands.
4. Relation of stand density to bud production, resin production in buds, and success of larval attack.

CONCLUSIONS

1. Size of terminal buds and number of lateral buds on apical clusters together provide a means for defining conditions under which the shoot moth is tested on ponderosa pine.
2. Probable resin production of lateral buds is less than that of terminal buds. Lateral buds have fewer and smaller resin canals, and their development lags behind that of terminal buds.
3. Size of buds as indicated by pith diameter, and size of resin canals, are directly related in both lateral and terminal buds.
4. Differences in bud numbers, probable differences in resin production between terminal and lateral buds, and phenology may be related to susceptibility of ponderosa pine to the European pine shoot moth.

LITERATURE CITED

- Axelton, Elvera A.
1967. Ponderosa pine bibliography through 1965. Intermountain Forest and Range Exp. Sta., U.S.D.A. Forest Serv. Res. Pap. INT-40, 150 pp., illus.
- Brookes, C. C., and Brown, J. M. B.
1936. Studies on the pine shoot moth (*Evetria buoliana* Schiff.). Bull. Forest. Comm. 16: 1-36.
- Cummings, W. H.
1967. Ponderosa pine regeneration and silvics references. Coop. State Res. Serv., U.S. Dep. Agr., 28 pp.
- Flora, Donald F.
1965. Economic evaluation of potential European pine shoot moth damage in the ponderosa pine region. Pacific Northwest Forest & Range Exp. Sta., U.S.D.A. Forest Serv. Res. Note PNW-22, 14 pp.
- Harris, P.
1960. Production of pine resin and its effect on survival of *Rhyacionia buoliana* (Schiff.) (Lepidoptera: Olethreutidae). Can. J. Zool. 38: 121-130.
- Heikkinen, Herman J., and Miller, William E.
1960. European pine shoot moth damage as related to red pine growth. U.S.D.A. Forest Serv., Lake States Forest Exp. Sta. Res. Pap. 83, 12 pp.
- Holst, M.
1963. Breeding resistance in pines to *Rhyacionia* moths. F.A.O. World Consultation on Forest Genetics and Tree Improvement. 17 pp.
- _____ and Heimbürger, C.
1955. The breeding of hard pine types resistant to the European pine shoot moth (*Rhyacionia buoliana* Schiff.) Forest. Chron. 31: 162-169.
- Mergen, F., Snyder, E. B., and Burley, J.
1966. Variation in coastal and insular slash pine of Mississippi and Alabama. Amer. Midland Natur. 76: 482-495.
- Miller, William E.
1967. The European pine shoot moth--ecology and control in the Lake States. Forest Sci. Monogr. 14, 72 pp.

Sacher, J. A.

1954. Structure and seasonal activity of the shoot apices of *Pinus lambertiana* and *Pinus ponderosa*. Amer. J. Bot. 41: 749-759.

Yates, H. O.

1966. Susceptibility of loblolly and slash pines to *Rhyacionia* spp. oviposition, injury, and damage. J. Econ. Entomol. 59: 1461-1464.

PNW-91

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VOLUME TABLES AND EQUATIONS FOR OLD-GROWTH WESTERN HEMLOCK
AND SITKA SPRUCE IN SOUTHEAST ALASKA

by

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ABSTRACT

Field measurements collected in 1961 and 1962 from southeast Alaska logging operations were used for computing volume equations and constructing tree volume tables. Regression analysis was used for estimating three kinds of tree volume with three independent variables. Equations were produced in both weighted and unweighted forms in testing for unequal volume variances. Weighted equations and those containing form class as an independent variable were superior to unweighted equations and those not containing form class variables. Combined species equations were superior to single species equation forms.

These volume tables were constructed from 1,013 trees measured in 1961 and 1962 at 21 widely dispersed logging operations on the Tongass National Forest in southeast Alaska. The sample is representative of commercial timber stands now being harvested. The top and stump measurements used conform closely to present harvesting practices.^{1/}

^{1/} Bones, James T. Comparing inventory and woods utilization standards in southeast Alaska. Northern Forest Exp. Sta. Tech. Note No. 54, 7 pp., illus. 1962.

Merchantable top for board-feet equals 40 percent of d.b.h. (diameter at breast height), but not less than 6 inches inside bark; merchantable top for cubic feet equals 4 inches inside bark. Stump heights are those actually cut and average 18 inches. Seventy-four percent of the stumps were between 10 and 25 inches high.

Field measurements for the board-foot tables were d.b.h., d.i.b. (diameter inside bark) at 16-foot intervals between the stump and merchantable top, and merchantable height in number of 16-foot logs. Measurements for the cubic-foot tables were d.b.h., d.i.b. at varying lengths between the stump and a 4-inch top, and height in number of 16-foot logs to a top that equals 40 percent of d.b.h., but not less than 6 inches inside bark. Both 16- and 32-foot form class were computed for each tree. International 1/4-inch and Scribner^{2/} log rule equations were used to compute board-foot tree volumes. Smalian's formula was used to compute cubic-foot volumes.

Equations were determined by regression analysis^{3/} to predict volume for the two species by the three volume measures. Weighted and unweighted equations were solved to see which gave the best fit to the data. The weighted equation proved superior in that it was more successful in satisfying the assumptions underlying the regression analysis. The unweighted equation was:

$$V_k = b_0 + b_1D + b_2D^2 + b_3H + b_4D^2H + b_5 \frac{1}{D^2} + b_6F_j$$

where:

V_k = board-foot or cubic-foot tree volume

D = d.b.h.

H = merchantable height in 16-foot logs

F_j = 16- or 32-foot form class

b_i = constants (see table 2)

Observations having unequal variances of volume are normally weighted by the reciprocal or inverse of their variances. Similar results were obtained^{4/} by weighting each variable of the equation by

^{2/} Bruce, Donald. A formula for the Scribner rule. J. Forest 23: 432-433. 1925.

^{3/} Boles, J. N. 40 - series--stepwise regression system. (Unpublished report.) Calif. Agr. Exp. Sta., Dep. Agr. Econ., Univ. Calif., Berkeley. 43 pp. June 1962.

^{4/} Furnival, George M. An index for comparing equations used in constructing volume tables. Forest Sci. 7: 337-341. 1961.

$(D^2H)^{-2}$. This gave the following weighted equation:

$$\frac{V_k}{D^2H} = b'_0 \frac{1}{D^2H} + b'_1 \frac{1}{DH} + b'_2 \frac{1}{H} + b'_3 \frac{1}{D^2} + b'_4 + b'_5 \frac{1}{D^4H} + b'_6 \frac{F_i}{D^2H}$$

where: b'_i = constants for the weighted equation.

All terms in the above equation must be multiplied by D^2H to convert it back to the unweighted form.

Table 1 presents standard errors of the estimated mean volumes in percent and multiple coefficients of determination (R^2), an index of the amount of variation accounted for by regression for the unweighted equations. Because the variation associated with D^2H is removed by the weighting technique before the regression is performed, R^2 could not be retrieved for the weighted form.

Weighting reduced standard errors of the equations for all species, form classes, and types of volume. The Sitka spruce equations are stronger than the western hemlock equations although based upon a smaller sample.

Form class improved the equation precision. Thirty-two-foot form class improved the Sitka spruce board-foot equations more than 16-foot form class; for western hemlock, the reverse is true. The cubic-foot equations for both tree species are better using the 16-foot form class.

Values for intercept constants and regression coefficients of the weighted equations are given in table 2. Equations containing these values can be used directly in electronic computer programs when processing timber cruise data.

In some cases, illogical volume estimates are obtained in the low diameter classes and outside the range of the original tree data. The equations should therefore be tested to assure that valid volume estimates are being given within the range of the tree data being processed.

Tables 3 to 8 will fill the needs of those workers desiring tree volume tables for field volume estimates or calculating volumes by hand at field stations. The form class equations were not used for these tables, because the increased precision by including the form class variable is overshadowed by the difficulty of accurately measuring form class in the field.

Although F-tests indicate that individual equations for spruce and hemlock are not significantly superior to a combined equation, separate volume tables are presented. The divergence of volumes for these species in the low and high diameter and height classes indicates an advantage of this separation.

Table 1.--Precision of alternative board-foot and cubic-foot volume equations

BOARD FEET (SCRIBNER RULE)					
Species	Form class used	Standard error of estimate		R ² for unweighted equation ^{1/}	Number of trees
		Weighted equation	Unweighted equation		
----- Percent -----					
Sitka spruce	None	8.57	18.31	0.972	266
	16-foot	7.41	13.92	.984	
	32-foot	7.16	12.76	.987	
Western hemlock	None	11.12	18.69	.961	747
	16-foot	8.20	14.29	.977	
	32-foot	8.81	14.27	.977	
Combined	None	10.55	18.95	.965	1,013
	16-foot	8.00	14.64	.979	
	32-foot	8.39	14.28	.980	
BOARD FEET (INTERNATIONAL 1/4-INCH RULE)					
Sitka spruce	None	8.90	17.90	.972	266
	16-foot	7.20	13.37	.984	
	32-foot	6.96	12.24	.987	
Western hemlock	None	10.78	17.97	.961	747
	16-foot	7.91	13.70	.978	
	32-foot	8.54	13.68	.978	
Combined	None	10.26	18.27	.965	1,013
	16-foot	7.76	14.03	.979	
	32-foot	8.15	13.68	.980	
CUBIC FEET					
Sitka spruce	None	9.80	14.32	.978	266
	16-foot	8.93	12.82	.982	
	32-foot	9.10	12.01	.985	
Western hemlock	None	10.49	16.55	.961	747
	16-foot	9.21	14.33	.970	
	32-foot	9.37	14.60	.969	
Combined	None	10.37	16.40	.966	1,013
	16-foot	9.26	14.56	.973	
	32-foot	9.40	14.38	.974	

^{1/} The multiple coefficient of determination (R²) could not be estimated for the weighted form of the equations.

Table 2.--Constants for weighted volume equations of southeast Alaska tree species

Species	Form class used	Intercept constant	Independent variable					F _j
			D	D ²	H	D ² H	1/D ²	
Sitka spruce	None	--	--	-0.22256	-21.06369	0.34399	7.219.0713	--
	16-foot	-304.2926	--	- .54625	-59.0693	.39191	-14,084.00	7.25558
	32-foot	-187.38916	--	- .53915	-86.65427	.39565	-14,794.00	8.23733
Western hemlock	None	--	--	--	-8.6308	.28348	--	--
	16-foot	484.10886	--	- .11060	-29.73546	.31567	--	6.97891
	32-foot	84.10443	--	- .39524	-64.80464	.36082	-13,497.00	5.45906
Combined	None	--	--	- .11546	-14.09611	.31378	3,653.44820	--
	16-foot	-464.35522	--	- .15525	-33.34669	.32678	--	6.88730
	32-foot	- 97.20730	--	- .43216	-68.45546	.37037	-13,247.00	5.81713
CONSTANTS FOR INTERNATIONAL 1/4-INCH BOARD-FOOT EQUATIONS								
Sitka spruce	None	--	--	- .22276	-13.51970	.35417	7,011.9961	--
	16-foot	-315.64641	--	- .56546	-53.46286	.40490	-15,422.00	7.57891
	32-foot	-193.47406	--	- .55793	-82.25466	.40879	-16,157.00	12.98374
Western hemlock	None	- 9.6512439	2.6510883	- .17949617	- 7.4021307	.320969	1,876.4131	--
	16-foot	-766.44019	17.729338	- .43703342	-23.419670	.32849136	12,662.188	7.3746037
	32-foot	- 96.860265	.68289865	- .42034489	-59.569917	.37298366	-14,107.924	5.707146
Combined	None	--	--	- .11259	- 6.38331	.32316	3,361.3556	--
	16-foot	-526.97453	5.94988	- .35391	-31.76929	.35106	--	7.22788
	32-foot	435.58416	- 6.34553	- .34539	-63.97341	.38436	-19,678.00	6.04978
CONSTANTS FOR CUBIC-FOOT EQUATIONS								
Sitka spruce	None	16.30566	--	--	- 3.09606	.04983	--	--
	16-foot	70.22160	--	- .07640	- 9.83336	.06079	- 4,421.30140	.87777
	32-foot	67.40064	--	- .04095	-10.97363	.05611	- 3,067.87990	.93612
Hemlock	None	--	--	.04915	--	.03912	269.92685	--
	16-foot	- 59.64022	--	.04926	- 1.68514	.03965	--	.83469
	32-foot	- 40.37296	1.53311	--	- 5.27334	.04321	--	.66296
Combined	None	--	--	.04589	--	.04015	391.15799	--
	16-foot	- 61.58925	1.13797	--	- 3.60359	.04505	--	.82038
	32-foot	- 8.30136	--	--	- 7.10379	.04834	- 1,853.8527	.70015

Table 3.--Volume table for old-growth Sitka spruce in southeast Alaska^{1/}
(In board feet, Scribner rule)

D.b.h. (D) ^{2/} (inches)	Merchantable height in 16-foot logs (H) ^{3/}										Basis ^{4/}
	1	2	3	4	5	6	7	8	9	10	
12	47	75	103	132	160	189					5
14		86	132	179	225	271					15
16		105	172	239	306	373					22
18		131	221	312	402	492					24
20		162	279	395	512	628					26
22			343	489	634	780	925	1,071			28
24			416	593	770	947	1,124	1,301			19
26			495	706	918	1,129	1,340	1,552			18
28			581	829	1,078	1,326	1,575	1,824			21
30			673	962	1,250	1,539	1,827	2,116			20
32				1,104	1,435	1,766	2,097	2,429	2,760		13
34				1,255	1,632	2,008	2,385	27,62	3,138		16
36				1,416	1,841	2,266	2,690	3,115	3,540		8
38				1,586	2,062	2,538	3,013	3,489	3,964		4
40				1,766	2,295	2,824	3,354	3,883	4,412		3
42					2,540	3,126	3,712	4,297	4,883	5,469	2
44					2,797	3,442	4,087	4,732	5,377	6,022	3
46					3,067	3,773	4,480	5,187	5,894	6,601	3
48					3,348	4,119	4,891	5,662	6,434	7,205	7
50					3,641	4,480	5,319	6,158	6,997	7,836	2
52					3,946	4,855	5,764	6,673	7,583	8,492	2
54					4,263	5,246	6,228	7,210	8,192	9,174	3
56					4,593	5,650	6,708	7,766	8,824	9,881	0
58					4,934	6,070	7,206	8,342	9,478	10,615	1
60					5,287	6,505	7,722	8,939	10,156	11,374	0

^{1/} Based on weighted equation:

$$V = -0.22256D^2 + 0.34399D^2H - 21.06369H + \frac{7219.07130}{D^2}$$

Standard error of estimate = 118.03 board feet or 8.57 percent of the mean volume.

^{2/} 12-inch class includes trees 11.0 to 12.9 inches d.b.h.

^{3/} Computed for 16.3-foot log lengths between logger stump and a top equaling 40 percent of d.b.h., but never less than 6.0 inches.

^{4/} Number of trees; range of data for 266 trees enclosed by solid line.

Table 4.--Volume table for old-growth Sitka spruce in southeast Alaska^{1/}
(In board-feet, International 1/4-inch rule)

D.b.h. (D) ^{2/} (inches)	Merchantable height in 16-foot logs (H) ^{3/}										Basis ^{4/}
	1	2	3	4	5	6	7	8	9	10	
12	54	92	129	166	204	241					5
14		104	160	216	272	327					15
16		125	202	279	356	433					22
18		152	253	354	456	557					24
20		185	313	441	569	697					26
22			380	538	696	854	1,012	1,170			28
24			455	646	836	1,027	1,217	1,408			19
26			537	763	989	1,215	1,441	1,667			18
28			627	891	1,155	1,419	1,683	1,947			21
30			723	1,028	1,333	1,639	1,944	2,249			20
32				1,175	1,524	1,874	2,223	2,572	2,921		13
34				1,332	1,728	2,124	2,520	2,916	3,312		16
36				1,499	1,944	2,390	2,835	3,281	3,726		8
38				1,675	2,173	2,671	3,168	3,666	4,164		4
40				1,861	2,414	2,967	3,520	4,073	4,626		3
42					2,667	3,278	3,890	4,501	5,112	5,723	2
44					2,933	3,605	4,277	4,950	5,622	6,294	3
46					3,211	3,947	4,683	5,419	6,155	6,891	3
48					3,502	4,305	5,107	5,910	6,712	7,515	7
50					3,805	4,677	5,549	6,421	7,293	8,165	2
52					4,121	5,065	6,009	6,953	7,898	8,842	2
54					4,449	5,468	6,487	7,507	8,526	9,545	3
56					4,789	5,887	6,984	8,081	9,178	10,275	0
58					5,142	6,320	7,498	8,676	9,854	11,032	1
60					5,507	6,769	8,030	9,292	10,553	11,815	0

^{1/} Based on weighted equation:

$$V = -0.22276D^2 + 0.35417D^2H - 13.51970H + \frac{7011.99610}{D^2}$$

Standard error of estimate = 122.56 board feet or 8.90 percent of the mean volume.

^{2/} 12-inch class includes trees 11.0 to 12.9 inches d.b.h.

^{3/} Computed for 16.3-foot log lengths between logger stump and a top equaling 40 percent of d.b.h., but never less than 6.0 inches.

^{4/} Number of trees; range of data for 266 trees enclosed by solid line.

Table 5.--Volume table for old-growth Sitka spruce in southeast Alaska^{1/}
(In cubic feet, Smalian formula)

D.b.h. (D) ^{2/} (inches)	Merchantable height in 16-foot logs (H) ^{3/}										Basis ^{4/}
	1	2	3	4	5	6	7	8	9	10	
12	20	24	28	33	37	41					5
14		30	36	43	50	56					15
16		36	45	55	65	74					22
18		42	55	68	81	95					24
20		50	67	84	100	117					26
22			79	100	121	142	163	184			28
24			93	119	144	170	195	221			19
26			108	139	169	200	230	261			18
28			124	160	196	232	268	304			21
30			142	183	225	267	309	350			20
32				208	256	304	352	400	448		13
34				234	289	343	398	452	507		16
36				262	324	385	447	508	570		8
38				292	361	429	498	567	636		4
40				323	399	476	553	629	706		3
42					440	525	610	695	779	864	2
44					483	577	670	763	857	950	3
46					528	630	733	835	937	1,040	3
48					575	687	798	910	1,022	1,133	7
50					624	745	867	988	1,100	1,231	2
52					674	806	938	1,069	1,201	1,333	2
54					727	870	1,012	1,154	1,296	1,438	3
56					782	935	1,088	1,242	1,395	1,548	0
58					839	1,003	1,168	1,333	1,497	1,662	1
60					898	1,074	1,250	1,427	1,603	1,779	0

^{1/} Based on weighted equation: $V = 16.30566 - 3.09606H + 0.04983D^2H$. Standard error of estimate = 22.02 cubic feet or 9.80 percent of the mean volume.

^{2/} 12-inch class includes trees 11.0 to 12.9 inches d.b.h.

^{3/} Computed for sections under 20 feet in length between logger stump and 4-inch d.i.b. top.

^{4/} Number of trees; range of data for 266 trees enclosed by solid line.

Table 6.--Volume table for old-growth western hemlock in southeast Alaska^{1/}

(In board feet, Scribner rule)

D.b.h. (D) ^{2/} (inches)	Merchantable height in 16-foot logs (H) ^{3/}										Basis ^{4/}
	1	2	3	4	5	6	7	8	9	10	
12	32	64	97	129	161						18
14	47	94	141	188	235	282	328				44
16		128	192	256	320	384	448				84
18		166	250	333	416	499	582				70
20		209	314	419	524	629	733				65
22		257	386	514	643	771	900				69
24			464	619	773	928	1,083	1,237			62
26			549	732	915	1,098	1,281	1,464			75
28			641	854	1,068	1,282	1,495	1,709			35
30			739	986	1,232	1,479	1,725	1,972			39
32			845	1,127	1,408	1,690	1,972	2,253			33
34			957	1,276	1,595	1,914	2,233	2,553			30
36			1,076	1,435	1,794	2,153	2,511	2,870			34
38			1,202	1,603	2,004	2,404	2,805	3,206			22
40			1,335	1,780	2,225	2,670	3,115	3,559			14
42				1,966	2,457	2,949	3,440	3,931	4,423		17
44				2,161	2,701	3,241	3,781	4,321	4,862		13
46				2,365	2,956	3,547	4,138	4,730	5,321		9
48				2,578	3,222	3,867	4,511	5,156	5,801		5
50				2,800	3,500	4,200	4,900	5,601	6,301		4
52					3,789	4,547	5,305	6,063	6,821	7,579	3
54					4,090	4,908	5,726	6,544	7,362	8,180	0
56					4,402	5,282	6,162	7,043	7,923	8,804	2
58					4,725	5,670	6,615	7,560	8,505	9,450	0
60					5,059	6,071	7,083	8,095	9,107	10,119	0

^{1/} Based on weighted equation: $V = -8.63080H + 0.28348D^2H$. Standard error of estimate = 115.22 board feet or 11.12 percent of the mean volume.

^{2/} 12-inch class includes trees 11.0 to 12.9 inches d.b.h.

^{3/} Computed for 16.3-foot log lengths between logger stump and a top equaling 40 percent of d.b.h., but never less than 6 inches.

^{4/} Number of trees; range of data for 747 trees enclosed by solid line.

Table 7.--Volume table for old-growth western hemlock in southeast Alaska^{1/}
(In board feet, International 1/4-inch rule)

D.b.h. (D) ^{2/} (inches)	Merchantable height in 16-foot logs (H) ^{3/}										Basis ^{4/}
	1	2	3	4	5	6	7	8	9	10	
12	48	87	126	165	203						18
14	57	113	168	224	279	335	390				44
16		144	218	293	368	443	517				84
18		179	275	372	469	565	662				70
20		218	339	460	581	702	823				65
22		262	409	557	705	853	1,001				69
24			486	664	841	1,019	1,196	1,374			62
26			569	779	989	1,198	1,408	1,617			75
28			659	903	1,147	1,392	1,636	1,880			35
30			755	1,036	1,318	1,599	1,881	2,162			39
32			857	1,178	1,500	1,821	2,142	2,463			33
34			965	1,329	1,693	2,056	2,420	2,784			30
36			1,080	1,489	1,897	2,306	2,715	3,123			34
38			1,201	1,657	2,114	2,570	3,026	3,482			22
40			1,329	1,835	2,341	2,847	3,354	3,860			14
42				2,021	2,580	3,139	3,698	4,256	4,815		17
44				2,216	2,830	3,444	4,058	4,672	5,286		13
46				2,420	3,092	3,764	4,436	5,107	5,779		9
48				2,633	3,365	4,097	4,830	5,562	6,294		5
50				2,855	3,650	4,445	5,240	6,035	6,830		4
52					3,946	4,806	5,667	6,527	7,388	8,248	3
54					4,253	5,182	6,111	7,039	7,968	8,896	0
56					4,572	5,571	6,571	7,570	8,569	9,568	2
58					4,902	5,975	7,047	8,120	9,192	10,264	0
60					5,244	6,392	7,540	8,688	9,836	10,985	0

^{1/} Based on weighted equation: $V = -9.6512 - 7.4021H + 2.6511D - 0.1795 D^2 + 0.3210D^2H + \frac{1876.4131}{D^2}$
Standard error of estimate = 119.55 board feet or 10.78 percent of the mean volume.

^{2/} 12-inch class includes trees 11.0 to 12.9 inches d.b.h.

^{3/} Computed for 16.3-foot log lengths between logger stump and a top equaling 40 percent of d.b.h., but never less than 6 inches.

^{4/} Number of trees; range of data for 747 trees enclosed by solid line.

Table 8.--Volume table for old-growth western hemlock in southeast Alaska^{1/}
(In cubic feet, Smalian formula)

D.b.h. (D) ^{2/} (inches)	Merchantable height in 16-foot logs (H) ^{3/}										Basis ^{4/}
	1	2	3	4	5	6	7	8	9	10	
12	15	20	26	31	37						18
14	19	26	34	42	49	57	65				44
16		34	44	54	64	74	84				84
18		42	55	67	80	93	105				70
20		52	67	83	99	114	130				65
22		62	81	100	119	138	157				69
24			96	119	141	164	186	209			62
26			113	139	166	192	219	245			75
28			131	162	192	223	254	284			35
30			150	185	221	256	291	326			39
32			171	211	251	291	331	371			33
34			193	238	283	328	374	419			30
36			216	267	317	368	419	469			34
38			241	297	354	410	467	523			22
40			267	329	392	454	517	579			14
42				363	432	501	570	639	708		17
44				398	474	550	625	701	777		13
46				435	518	601	684	766	849		9
48				474	564	654	744	834	925		5
50				514	612	710	808	905	1,003		4
52					662	768	873	979	1,085	1,191	3
54					714	828	942	1,056	1,170	1,284	0
56					768	890	1,013	1,136	1,258	1,381	2
58					823	955	1,087	1,218	1,350	1,481	0
60					881	1,022	1,163	1,304	1,444	1,585	0

^{1/} Based on weighted equation: $V = 0.04915D^2 + 0.03912D^2H + \frac{269.92685}{D^2}$. Standard error of estimate = 19.11 cubic feet or 10.49 percent of the mean volume.

^{2/} 12-inch class includes trees 11.0 to 12.9 inches d.b.h.

^{3/} Computed for sections under 20 feet in length between logger stump and 4-inch d.i.b. top.

^{4/} Number of trees; range of data for 747 trees enclosed by solid line.

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EFFECTS OF ARTIFICIAL FLOODING ON SEEDLING SURVIVAL AND GROWTH
OF SIX NORTHWESTERN TREE SPECIES

by

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ABSTRACT

Seedlings of Douglas-fir, Sitka spruce, western hemlock, western redcedar, lodgepole pine, and red alder were inundated in tanks for various lengths of time in both winter and summer. Winter flooding for periods of 1 to 4 weeks severely injured Douglas-fir but had little or no effect on other species. Summer flooding for 4 and 8 weeks affected all six species--many seedlings died, and many formed adventitious roots at the waterline. Western redcedar and lodgepole pine seemed to be the most flood-tolerant species; red alder, Sitka spruce, and western hemlock seemed to be less tolerant; and Douglas-fir was extremely intolerant of flooding.

INTRODUCTION

Flood-plain forests in coastal Oregon and Washington are often inundated for short periods during the winter rainy season. Swamps are sometimes flooded for months, as are areas adjacent to water storage reservoirs throughout the Pacific Northwest. Periodically flooded areas do not involve a high percentage of total forest land area but are often extremely valuable in terms of potential productivity, esthetics, or recreational use. Maximum timber values can be realized on these areas only if they are managed for flood-tolerant species.

Surprisingly little is known about the flood tolerance of northwestern trees. Brink (1954) studied several tree species affected by

the Fraser River flood of June and July 1948. He concluded that Douglas-fir and red alder were very vulnerable to floodwater. Western hemlock was somewhat less vulnerable and lodgepole pine, western redcedar, and Sitka spruce were judged most flood tolerant. Brink noted that cold, swift water seemed to be less damaging than warm, stagnant water. But his observations were qualitative; apparently, no quantitative measurements of flood tolerance are available for Pacific Northwest species.

More flood-tolerance information is available for species in other regions. Ahlgren and Hansen (1957), Green (1947), and Yeager (1949) studied flood tolerance in mixed-species forest stands in Minnesota, Iowa, and Illinois. They compared species tolerance under the natural conditions that occurred in the stands and did not control flooding depth or duration.

Flooding depth and duration have been artificially controlled to determine the relative flood tolerance of several eastern hardwoods. Hosner (1960) determined the relative tolerance of 14 hardwood species by completely inundating 1-year-old seedlings. Hosner and Boyce (1962), also, determined the relative tolerance of hardwood seedlings to a 1-inch inundation. Yelenosky (1963) used a 3-inch inundation to compare the flood tolerance of yellow-poplar, white oak, sugar maple, honey locust, and American elm. McAlpine (1961) compared yellow-poplar, sweetgum, and green ash and noted tolerance differences between the dormant and growing seasons.

Controlled artificial flooding has also been used to determine the flood tolerances of several eastern conifers. Williston (1962) submerged 1-year-old loblolly pine seedlings in northern Mississippi. They survived 32 days of total submergence during the dormant season but only 12 days during the growing season. Survival of seedlings totally submerged and seedlings submerged only to the root collar did not differ significantly. Hunt (1951) subjected seedlings of shortleaf, loblolly, and pond pine to four flooding regimes and found that all three species were flood tolerant. Walker, Green, and Daniels (1961) found that loblolly pine survived better than slash pine when both were inundated to a depth of 8 inches, but surviving slash pines grew faster after drainage. Lees (1964) flooded 1- and 2-year-old white spruce seedlings in the laboratory. The 2-year-old seedlings were more flood tolerant, but all seedlings died when totally immersed for 14 days.

Controlled, artificial flooding was used in the present study to investigate the relative flood tolerance of six northwestern species: Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western redcedar (*Thuja plicata* Donn), lodgepole pine

from the Oregon coast (*Pinus contorta* Dougl.), and red alder (*Alnus rubra* Bong.).

MATERIALS AND METHODS

Seedlings of all six species were grown from seeds collected near the Pacific coast (table 1). Seeds were stratified at 4° C. for 30 days and germinated on moist filter paper. Germinated seeds were planted in April 1966 in a mixture of four parts of loam soil^{1/} to one part of peat moss, which had been screened and blended before 854-gram portions were weighed into 162 1-quart plastic pots. Five germinated seeds--all of the same species--were planted in each pot, and pot locations were completely randomized, both by species and by assigned flooding treatment, on a greenhouse bench. Summer greenhouse temperatures varied from 16° to 32° C. All pots were equally watered daily; they were equally fertilized with 3 grams of 6-10-4 fertilizer in August 1966. In September, the seedlings were thinned to leave the two largest seedlings in each pot. Greenhouse heat was turned off in October, and all seedlings were dormant by December.

Table 1.--*Sources of seeds used in study*

Species	Location	Elevation
		<u>Feet</u>
Douglas-fir	Sand Lake, Oregon	300
Sitka spruce	Otis, Oregon	500
Western hemlock	Otis, Oregon	500
Western redcedar	Vancouver Island, B.C.	500
Lodgepole pine	Pacific City, Oregon	200
Red alder	Otis, Oregon	200

Two 122- by 122- by 24-centimeter wooden tanks were lined with polyethylene and placed on a bench in the unheated greenhouse (fig. 1). Pots to be flooded were randomized the same way in each tank in January 1967, and tapwater was added until all pots were flooded to a level 3 centimeters above the soil surface. Approximately 170 liters of water were added to each tank. An aquarium pump, air stone, and water pump aerated and circulated water in one tank at a rate of 3 liters per minute. Water in the second tank was left stagnant.

^{1/} 44 percent sand, 39 percent silt, 17 percent clay.



Figure 1.--*Flooding-tanks and seedlings at the beginning of the winter flooding period. The aerated tank is in the foreground.*

Each of the six species was subjected to nine treatments:

- 24-hour inundation, with aeration
- 24-hour inundation, without aeration
- 1-week inundation, with aeration
- 1-week inundation, without aeration
- 2-week inundation, with aeration
- 2-week inundation, without aeration
- 4-week inundation, with aeration
- 4-week inundation, without aeration
- Control (no inundation)

Each species treatment was replicated three times with three pots (six seedlings). All inundation treatments were started at the same time. Flood-treated pots were then successively removed after 24 hours, 1 week, 2 weeks, and 4 weeks. Control pots were left on the growing bench in their original randomized positions, and the flooded pots were replaced in their original randomized order after being removed from the tanks. Average greenhouse temperatures during the treatment period were 10⁰ C. in the daytime, 7⁰ C. at night. All seedlings remained dormant during the treatments.

By June 1967, it was evident that the dormant flooding treatments

had little effect on most of the species--only the Douglas-firs, inundated for long periods, died or showed reduced growth. Seedling shoot lengths of all species in pots from the 24-hour treatments were measured and compared with the controls in an analysis of variance. There were no significant treatment differences. Seedlings from the 24-hour winter treatments were therefore subjected to a summer flooding treatment in a single, stagnant-water tank. Pots containing these seedlings were randomized and flooded to 3 centimeters above the soil surface for periods of 4 and 8 weeks. Six pots of each species were immersed at the same time in June 1967. Three of these pots were removed after 4 weeks and placed back on the growing bench; three were removed after 8 weeks. All seedlings--winter treatment, summer treatment, and controls--were maintained in the greenhouse until the end of October 1967.

The largest surviving seedling in each pot was then washed free of soil, measured, and weighed. The following parameters were recorded:

- Number of surviving seedlings per pot
- Shoot weight
- Root weight
- Total weight
- Shoot length
- Root-surface area
- Shoot:root ratio (by weight)

All weights were measured after drying the seedlings for 48 hours at 65° C. Root-surface areas were estimated by use of the Carley and Watson (1966) method.

RESULTS

Average survival percentages, total seedling weights, and root-surface areas are listed in tables 2 through 5. Shoot weights, root weights, and shoot:root ratios expressed essentially similar species and treatment relationships. They are not presented here.

Winter inundation did not significantly affect the survival or growth of western hemlock, red alder, Sitka spruce, lodgepole pine, and western redcedar. The five species had significantly different weights, shoot lengths, root-surface areas, and shoot:root ratios when species were compared, but an analysis of variance showed no significant treatment differences or species-treatment interactions.

Table 2.--Average seedling survival by species and flooding treatment

(In percent)

Treatment	Douglas- fir	Western hemlock	Red alder	Sitka spruce	Lodgepole pine	Western redceda
Control (no inundation)	100	100	100	100	100	100
Winter inundation:						
1 week--						
Aerated	65	100	100	100	100	100
Stagnant	100	100	100	100	100	100
2 weeks--						
Aerated	65	100	100	100	100	100
Stagnant	85	100	100	100	100	100
4 weeks--						
Aerated	0	100	100	100	100	100
Stagnant	50	100	100	100	100	100
Summer inundation:						
4 weeks, stagnant	0	34	50	84	100	100
8 weeks, stagnant	0	16	65	34	50	100

Table 3.--Average total weight of largest surviving seedling per pot
by species and flooding treatment

(In grams)

Treatment	Douglas- fir	Western hemlock	Red alder	Sitka spruce	Lodgepole pine	Western redcedar
Control (no inundation)	5.80	3.71	21.49	5.54	6.26	7.88
Winter inundation:						
1 week--						
Aerated	3.00	2.58	23.18	3.97	6.52	6.73
Stagnant	3.30	2.55	24.07	3.17	6.43	4.61
2 weeks--						
Aerated	3.62	2.63	17.71	4.41	5.52	6.06
Stagnant	5.44	2.15	23.21	4.70	6.15	5.53
4 weeks--						
Aerated	--	3.24	22.95	4.16	7.95	6.73
Stagnant	2.14	2.48	19.97	5.28	8.00	5.64
Summer inundation:						
4 weeks, stagnant	--	1.42	21.45	1.89	5.84	5.43
8 weeks, stagnant	--	.89	24.37	1.90	6.14	3.06

Table 4.--Average root-surface area of largest surviving seedling per pot, expressed as grams of calcium nitrate solution adsorbed in 10-second dip by species and flooding treatment

Treatment	Douglas-fir	Western hemlock	Red alder	Sitka spruce	Lodgepole pine	Western redcedar
Control (no inundation)	6.6	4.8	18.7	7.2	6.9	12.9
Winter inundation:						
1 week--						
Aerated	4.1	3.5	18.1	4.9	8.4	12.2
Stagnant	4.3	3.1	17.3	4.0	6.4	6.9
2 weeks--						
Aerated	4.9	2.4	16.8	6.0	5.5	9.8
Stagnant	6.2	1.9	14.9	5.5	6.6	7.1
4 weeks--						
Aerated	--	3.4	18.5	5.7	8.7	11.7
Stagnant	2.5	2.9	15.9	6.9	12.4	8.7
Summer inundation:						
4 weeks, stagnant	--	.6	17.8	2.7	5.4	6.9
8 weeks, stagnant	--	.2	18.0	1.8	4.5	2.5

Table 5.--Average top length of largest surviving seedling per pot, by species and flooding treatment
(In centimeters)

Treatment	Douglas-fir	Western hemlock	Red alder	Sitka spruce	Lodgepole pine	Western redcedar
Control (no inundation)	19.3	19.0	104.7	19.0	25.7	30.7
Winter inundation:						
1 week--						
Aerated	12.0	17.7	111.3	17.7	21.7	28.7
Stagnant	17.3	18.7	112.7	17.3	25.0	25.0
2 weeks--						
Aerated	14.0	17.3	111.7	19.3	28.3	25.7
Stagnant	20.0	17.3	98.7	20.7	25.7	29.7
4 weeks--						
Aerated	--	22.0	108.3	19.0	26.7	28.7
Stagnant	9.3	15.0	107.7	23.7	27.7	27.3
Summer inundation:						
4 weeks, stagnant	--	15.0	94.5	17.0	23.7	27.3
8 weeks, stagnant	--	15.0	123.0	16.0	23.3	23.0

Winter inundation did affect the survival and growth of Douglas-fir. Even 1 week of winter inundation was detrimental. Four weeks were disastrous. Aerated floodwater was more damaging to Douglas-fir than stagnant water.

Summer flooding effects were more pronounced than the winter effects, but more difficult to interpret. The growing seedlings reacted to the summer inundation in several ways, and variation was extreme. Survival was erratic, differing from pot to pot within the same species and treatment. However, both western redcedar and lodgepole pine survived significantly better than Douglas-fir after 4 weeks of summer flooding. Total seedling weights were reduced by flooding. Root-surface areas were significantly reduced, but shoot lengths were not significantly affected by the inundation.

Much of the variation in survival and growth after summer inundation appeared to be related to waterline phenomena. All of the flooded Douglas-fir seedling stems were swollen at the waterline, as if they

had been girdled (fig. 2). Roots of all inundated Douglas-fir seedlings had dead cambiums, but the shoots remained green and healthy looking until October. The flooded Douglas-firs with dead roots were judged to be dead.



Figure 2.--¹Douglas-fir seedling inundated for 8 weeks in the summer. Note dead root system and swelling at the waterline.

Alder seedlings that formed adventitious root systems at the water-line (figs. 3 and 4) continued to live and grow even after 8 weeks of summer flooding. Those that failed to form adventitious roots died after 4 weeks of flooding.

Figure 3.--Alder seedlings after 4-week summer inundation. Note small adventitious root system on left seedling.



Figure 4.--Alder seedlings after 8-week summer inundation. The adventitious roots pictured here and in figure 3 withered soon after being removed from the water.



All summer-flooded western redcedar seedlings formed adventitious roots just below the waterline and survived. However, summer inundation decreased the growth of cedar seedlings, the effect increasing with flood duration.

All of the lodgepole pine seedlings survived 4 weeks of summer flooding, but half died after 8 weeks of flooding. Summer flooding did not seem to affect the growth of surviving lodgepole pine seedlings.

Both Sitka spruce and western hemlock were severely affected by the summer inundation. Survival and growth declined with increased flooding time in both species, but spruce seemed to be more flood tolerant than hemlock.

DISCUSSION

Short periods of winter flooding probably will not injure western hemlock, red alder, Sitka spruce, lodgepole pine, or western redcedar seedlings; these species may be grown on flood plains where shallow water tables do not affect growth. Floodwater tolerance and shallow water table tolerance can be quite different, however, and the two characteristics should not be confused. Species uninjured by temporary flooding with subsequent drainage may be unable to survive on areas which have permanently shallow water tables, even if these areas are only briefly inundated. Data presented here apply only to flood tolerance.

Douglas-fir seedlings are very intolerant of flooding. They should not be planted in areas subject to inundation even if the inundation occurs for only short periods in the winter. The adverse effect of aeration upon Douglas-fir survival and growth in the winter-flooding treatments is puzzling, for Brink's 1954 observations indicated that flowing, aerated water was less damaging than stagnant water. Perhaps air was trapped in the pots when they were inundated, and perhaps the circulating water in the aerated tank absorbed this air faster than did the stagnant water in the other tank.

All six species were more sensitive to summer flooding than they were to winter flooding, and summer survival seemed to depend upon the ability of individual trees to form adventitious roots. Kramer (1951) and Yelenosky (1963) also noted this relationship between the survival of inundated trees and adventitious root formation. The peculiar situation observed in summer-inundated Douglas-fir, where roots were dead and shoots stayed green, may have been the result of water absorption by dead roots. Kramer (1933) found that dead pine roots absorbed enough water to keep the shoots green and unwilted for a time, even though adventitious roots were not formed. The swollen area near the waterline on inundated Douglas-firs (fig. 2) probably

resulted from carbohydrate accumulation when flooding interfered with downward translocation (Kramer 1951).

Statistically valid flood-tolerance ratings for each of the six species cannot be formulated from the data presented in tables 2 through 5. However, seedlings of the species may be tentatively grouped in terms of relative flood tolerance: Western redcedar and lodgepole pine seem to be the most flood tolerant; red alder, Sitka spruce, and western hemlock are intermediately tolerant; and Douglas-fir is extremely intolerant.

LITERATURE CITED

Ahlgren, Clifford E., and Hansen, Henry L.

1957. Some effects of temporary flooding on coniferous trees.
J. Forest. 55: 647-650.

Brink, V. C.

1954. Survival of plants under flood in the lower Fraser River Valley, British Columbia. Ecology 35: 94-95.

Carley, H. E., and Watson, R. D.

1966. A new gravimetric method for estimating root-surface areas.
Soil Sci. 102: 289-291.

Green, William E.

1947. Effect of water impoundment on tree mortality and growth.
J. Forest. 45: 118-120.

Hosner, John F.

1960. Relative tolerance to complete inundation of fourteen bottomland tree species. Forest Sci. 6: 246-251.

_____ and Boyce, Stephen G.

1962. Tolerance to water saturated soil of various bottomland hardwoods. Forest Sci. 8: 180-186.

Hunt, Francis M.

1951. Effect of flooded soil on growth of pine seedlings. Plant Physiol. 26: 363-368.

Kramer, Paul J.

1933. The intake of water through dead root systems and its relation to the problem of absorption by transpiring plants
Amer. J. Bot. 20: 481-492.

- _____ 1951. Causes of injury to plants resulting from flooding of the soil. Plant. Physiol. 26: 722-736.

- Lees, J. C.
1964. Tolerance of white spruce seedlings to flooding. Forest. Chron. 40(2): 221-224.
- McAlpine, Robert G.
1961. Yellow-poplar seedlings intolerant to flooding. J. Forest. 59: 566-568.
- Walker, Laurence C., Greene, R. Lamar, and Daniels, Joe M.
1961. Flooding and drainage effects on slash and loblolly pine seedlings. Forest Sci. 7: 2-15.
- Williston, Hamlin L.
1962. Loblolly seedlings survive twelve days' submergence. J. Forest. 60: 412.
- Yeager, L. E.
1949. Effect of permanent flooding in a river bottom area. Illinois Natur. Hist. Surv. Bull. 25, art. 2.
- Yelenosky, George.
1963. Soil aeration and tree growth. Int. Shade Tree Conf. Proc. 39: 16-25.

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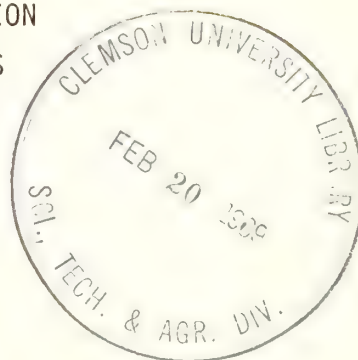
A COMPUTER PROGRAM FOR SCHEDULING ALLOWABLE CUT
USING EITHER AREA OR VOLUME REGULATION
DURING SEQUENTIAL PLANNING PERIODS

by

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and

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ABSTRACT

This Note describes a computer program, SORAC, which calculates allowable cut using either area or volume regulation at the beginning of each planning period within a rotation. This program enables the timber management planner to trace future allowable cut over time and to introduce his expectations as program inputs for every planning period. SORAC output is compared with outputs of AREA and ARVOL computer programs for a sample forest management unit.

INTRODUCTION

This publication announces the features, functions, and availability of the SORAC computer program, developed in connection with a study of timber management planning on the Pacific Northwest National Forests. This program simulates the process that forest managers commonly use in planning the allowable cut.

Timber harvest scheduling is one of the most challenging decisions facing forest managers today as the demand for timber increases along with pressure for alternative land uses. In the Douglas-fir region of the Pacific Northwest, managers of National Forest timberlands have seen actual cuts rise to equal planned or allowable cuts. In such a pressurized managerial environment, it is important that timber production scheduling be efficiently handled and integrated into the total decisionmaking system as smoothly as possible.

Traditionally, timber harvest scheduling has been accomplished by manual calculation with either the volume or area regulation method. Manual calculation of allowable cut is both extremely time consuming and error propagating. This is especially true of the volume regulation method which determines cut through an iterative procedure.

Computer simulation models, including AREA, ARVOL, and SORAC,^{1/} were recently developed to facilitate calculating allowable cut by these traditional methods. ARVOL^{2/} permits the analyst to quickly and accurately examine allowable cut under a range of conditions, assuming volume regulation, and AREA^{3/} provides similar facility in the case of area regulation. This Note assumes that volume regulation and the area-volume check method are synonymous.

Although the ARVOL and AREA computer programs can more rapidly, accurately, and comprehensively calculate annual allowable cut than

^{1/} ARVOL, AREA, and SORAC are products of the Timber Management Decision Systems (TIMADS) study. TIMADS, a continuing cooperative research effort of the Pacific Northwest Forest and Range Experiment Station and the Pacific Northwest Region of the Forest Service, U.S. Department of Agriculture, is a long-term study designed to provide forest managers with a more effective planning system. None of these programs include intermediate cuts in the allowable cut totals.

^{2/} Chappelle, Daniel E. A computer program for calculating allowable cut using the area-volume check method. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Res. Note PNW-44, 4 pp. 1966.

^{3/} Sassaman, Robert W., and Chappelle, Daniel E. A computer program for calculating allowable cut using area regulation and a comparison with the ARVOL method. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Res. Note PNW-63, 7 pp. 1967.

previous methods, traditional approaches to timber harvest scheduling do not realistically simulate the management decision process over time.

Traditional regulation methods, including those simulated by ARVOL and AREA, are one-time, static approaches to a dynamic planning situation. However, in practice, National Forest timber management plans are revised periodically. Hence, the allowable cut decision is evaluated periodically during a rotation or conversion period. On the west side of the Cascade Range, either area or volume regulation is applied in every planning period^{4/} to the most recent working circle data. During these reevaluations, various parameters of the planning model are updated (e.g., timber yields, rotation length, etc.). Parameter values may change from planning period to planning period because either actual conditions will have changed or managers will have expectations of change.

Also, the traditional regulation models assume a fixed investment horizon, whereas decisionmaking operates within a constantly changing investment horizon. Forest managers have recognized this constantly changing investment horizon in their adoption of such policies as sustained yield and multiple use. These policies constrain the range of management alternatives, although no computer models have been available to show the implications of these constraints.

The development of SORAC^{5/} is a step toward a continuous, computerized, forest management, decisionmaking system, as it combines a continuously changing time horizon with frequent policy reevaluation. SORAC calculates the allowable cut for each planning period and thereby provides the opportunity to incorporate effects of expected management changes into the allowable cut decision process within a rotation.

With SORAC, forest managers can introduce their expectations for every planning period within a rotation, thereby permitting them to test various management strategies and facilitating the selection of strategies most likely to fulfill the goals of the firm. In contrast, the AREA and ARVOL computer models, as generally used, do not simulate the timber harvest scheduling process because they permit the analyst

^{4/} Planning period is defined as the interval of time in which parameters of the planning model (e.g., yield equation coefficients) do not change in value. This may also be thought of as the interval between regular management plan revisions. A decade is a common planning period in the Pacific Northwest.

^{5/} The acronym, SORAC, was derived from the words "Short Run Allowable Cut." The method of analysis is considered shortrun since planning is done sequentially, planning period by planning period, by rather short intervals.

to introduce expected management and environmental changes only at the beginning of a rotation.

DESCRIPTION OF SORAC

SORAC Features

The SORAC program is coded in FORTRAN IV. Program characteristics include:

1. Forecasts annual allowable cut for each planning period within a rotation. The length and number of planning periods to be examined are selected by the analyst.
2. Provides a choice of using either area or volume regulation within each planning period.
3. Allows the analyst to specify the volume unit; e.g., board feet, cubic feet, etc.
4. Provides for automatic updating of data at the end of a planning period for use in the next allowable cut calculation, if desired.

If automatic update is not desired, then new data must be read.

If automatic updating of data is desired, all parameters continue at previous levels and the rotation age must be evenly divisible by the planning period.

5. Provides the advantage of dealing in value as well as volume by introducing stumpage prices into the allowable cut calculations.
6. Has the flexibility of using a separate empirical yield equation for each stand, whether intensively or extensively managed.
7. Has capacity for analyzing a maximum of 80 stands^{6/} in one problem.
8. Allows a separate yield equation for intensively managed stands to be entered for each stand or allows entering a normal yield equation for use in conjunction with empirical yield equations for extensively managed stands.

^{6/} In this discussion, an age class is generally considered to be a stand. However, it is possible that several stands can be the same age.

9. Allows both extensively and intensively managed stands to be included in all analyses.
10. Recognizes that regeneration period is an input and hence may be varied as desired by the analyst. Negative age classes may be assigned in those cases where a period longer than the assumed regeneration period is likely to occur.
11. Permits stacking of problems; i.e., a number of analyses may be completed in one computer run.

Some analysts will wish to replace previously released ARVOL and AREA computer programs with SORAC, because analyses which may be completed by ARVOL or AREA may be handled by selecting various SORAC options. However, SORAC can accomplish much more than ARVOL or AREA, as noted above. Program characteristics 1-8 are unique to SORAC as contrasted to ARVOL and AREA.

INPUTS

1. Number of problems to be run.
 2. Problem title.
 3. Stand regeneration indicator (i.e., an indicator as to whether zero-age stands are regenerated or bare).
 4. Trial allowable cut, volume unit.
 5. Number of stands.
 6. Beginning year of planning horizon.
 7. Ending year of planning horizon.
 8. Volume unit title.
 9. Age of stands.
 10. Area distribution by stands, acres.
 11. Physical input control for yield equation coefficients and for the percentage of area intensively managed.
 12. Stumpage price input control.
 13. Cut regulation method control (i.e., either volume or area regulation).
 14. Rotation, years.
 15. Planning period, years.
 16. Minimum cutting age, years.^{7/}
 17. Regeneration period, years.
 18. An identifier that specifies which yield equations are to be used for intensively managed stands.
 19. Coefficients of price equations for extensively and intensively managed stands.
 20. Coefficients of empirical yield equations for extensively managed stands.
 21. Coefficients of yield equations for intensively managed stands and percentage of area intensively managed.
- Or
- Normal yield coefficients, the number of the first intensively managed stand, and the percentage of area intensively managed.
22. Yield multiplier, a constant percentage increase in previous physical yield.
 23. An addition to the percentage of area intensively managed for each stand, if desired.
 24. An end-of-problem indicator.

OUTPUTS

- Outputs 1 through 10 are listed for each stand. Outputs 11 through 20 are aggregates of stand values:
1. Acreage.
 2. Average age when cut, years.
 3. Yield per acre when cut, volume unit.
 4. Total yield when cut, volume unit.
 5. Time required to cut the total yield, years.
 6. Cumulated time required to cut the total yield, years.
 7. Area to cut annually, acres (assuming volume regulation) or average volume to cut annually (assuming area regulation), volume unit.
 8. Area intensively managed, percent of total area.
 9. Average price, dollars per thousand volume units.
 10. Total value of yield, dollars.
 11. Total area, acres.
 12. Total volume, volume unit.
 13. Total value of rotation harvest, dollars.
 14. Average annual allowable cut during planning period, volume unit.
 15. Average area cut per year, acres.
 16. Average yield per acre, volume unit.
 17. Average yield per acre per year, volume unit.
 18. Regeneration period, years.
 19. Area cut (acres) each year of the rotation assuming volume regulation.
- Or
- Volume cut each year of the rotation assuming area regulation.
20. Value of timber harvested each year of the rotation, dollars.
 21. Value of average annual allowable cut during period.

^{7/} Minimum cutting age is not a constraint. It is simply a more accurate starting point than stand age for the procedure used to determine the number of years required to cut any given stand under the volume regulation option. Therefore, it is possible to calculate an average age-when-cut for a stand with lower than the minimum cutting age.

APPLICATION OF SORAC

An example of the use of SORAC and an illustration of how its output can differ from ARVOL and AREA outputs is illustrated for a sample management unit in figures 1 and 2. The stand structure for the sample management unit is shown in table 1. Note that the unit contains a predominance of overmature stands (in excess of rotation age of 90 years). The analyses discussed here were completed with identical data, and it was assumed that levels of management intensity and utilization standards remain constant throughout the entire period of 180 years (two 90-year rotations). Also, the oldest stands are assumed to be cut first in all cases.

Table 1.--*Stand structure of sample management unit at beginning of first planning period*

Age	Area	Age	Area
<i>Years</i>	<i>Acres</i>	<i>Years</i>	<i>Acres</i>
450	12,725	110	20,362
400	71,896	100	21,632
350	62,988	90	14,633
300	34,358	80	28,630
250	29,267	70	26,723
200	15,270	60	23,542
180	5,726	50	14,634
170	6,363	40	19,087
160	6,362	30	8,907
150	9,543	20	9,544
140	12,725	10	13,361
130	15,905	0	15,905
120	14,634		

In figure 1, annual allowable cut is shown for each year of the period for SORAC (volume regulation option), ARVOL, and AREA. SORAC and ARVOL assume volume regulation, but AREA assumes area regulation. Figure 1 indicates the effect of one characteristic of SORAC; namely, that the program always looks ahead a period of time equal to one rotation when allowable cut is calculated. For example, the cut during the first planning period (years 0-10 of the first rotation) is calculated with a goal of even flow during the entire first rotation (years 0-90), whereas the cut during the second planning period is based on years 10-100 (i.e., looking ahead to the end of the first planning period of the second rotation), etc. It is this characteristic that causes the SORAC allowable cut trend line to significantly differ from

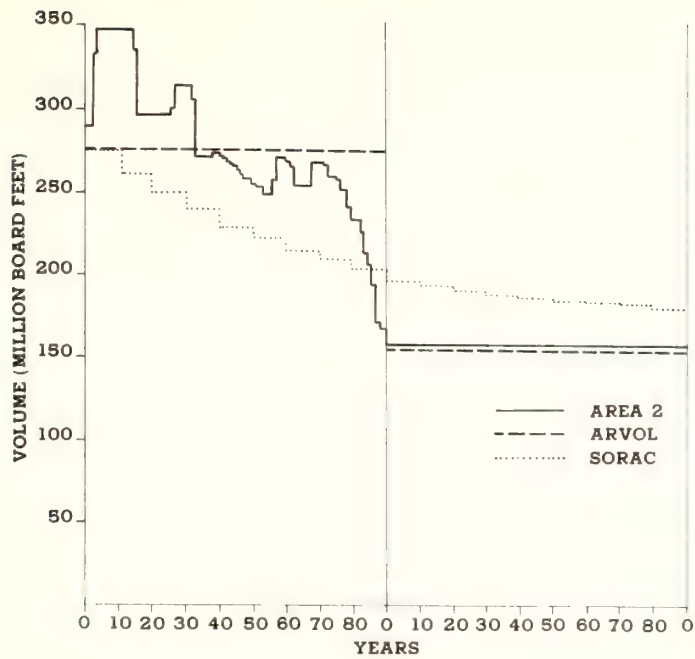


Figure 1.--Annual allowable cut determined with SORAC (volume regulation option) and a comparison with levels calculated with ARVOL and AREA.

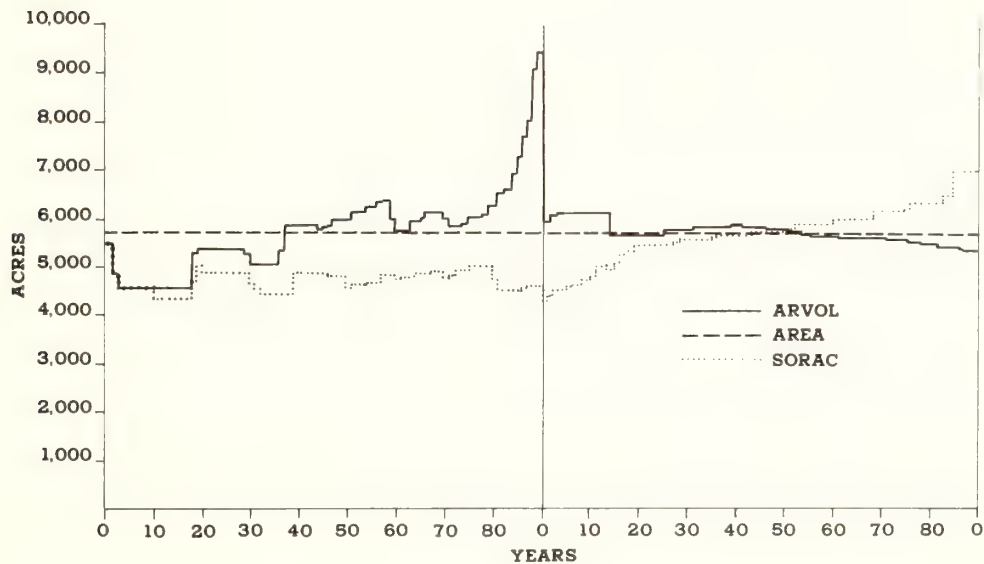


Figure 2.--Area cut annually determined with SORAC (volume regulation option) and a comparison with levels calculated with ARVOL and AREA.

the ARVOL line. Whereas ARVOL provides for the maintenance of even flow of timber during each rotation, the cut level during the second rotation is only approximately 60 percent of the first rotation cut. In contrast, the SORAC trend line declines more gradually, ending at year 180 with a cut nearly 70 percent of the first-year cut.

This effect occurs because the cut of overrotation-age timber (>90 years) is spread over a longer period of time than in the case of ARVOL; that is, the investment horizon is longer. In SORAC, the allowable cut is required to be even flow, but only within a planning period. Note that the SORAC level of cut during the first planning period is identical to that of ARVOL.

Figure 1 indicates that SORAC output, from an analysis in which volume regulation is assumed by the user for every planning period, differs from ARVOL output even when management assumptions are held constant and identical data are used for all planning periods.

Figure 2 shows the acres cut over the 180-year period with the SORAC volume regulation option. AREA assumes area regulation, but ARVOL assumes volume regulation. The area cut is less during the first rotation for SORAC after the initial planning period than for ARVOL because the volume cut is lower. Maximum deviation from the AREA trend line occurs with ARVOL because the old-growth timber is harvested faster than with the SORAC schedule. In SORAC, timber cut at the beginning of the second rotation is approximately 150 years old, whereas following the ARVOL schedule results in rotation-age timber being cut at that time.

One should be aware that using the area regulation option of SORAC for each planning period with constant parameter values will yield the same trend line as AREA, both for volume and acres cut.

In practice, SORAC generally would not be used in the manner indicated above. That is, parameters would not likely be held constant, and regulation method may change within a rotation. SORAC is a flexible planning tool into which managers may insert their expectations and which will provide implications of managerial action. Also, as noted earlier, SORAC is a computer model that simulates the allowable cut decision process used by many forest managers in the Pacific Northwest and other regions.

OPERATION OF THE SORAC COMPUTER PROGRAM

The SORAC program, when operated under the volume regulation option, prints only the final allowable cut and related data. The number of trial cuts required to arrive at the final cut is a function of the accuracy of the starting approximation of allowable cut, which is a required input to the program. The program begins at the cut

level set by the user and converges toward the final allowable cut by an iterative procedure. When final cut is determined, it and associated outputs are printed and the program either continues into the data-update procedure, which develops input data, or new input data are read for the cut calculation appropriate to the next planning period.

When the area regulation option is used, no iteration procedure is required because the final cut is calculated directly. Once the cut is determined, the program either proceeds into the data-update procedure or reads new data, as it does with volume regulation.

Time requirements for a problem of any given size cannot be estimated with certainty because speed of solution is dependent upon the first approximation of allowable cut and the amount of input data. However, some typical operation times follow:

<u>Number of stands</u>	<u>Regulation method</u>	<u>Rotation</u> (Years)	<u>Number of planning periods per rotation</u>	<u>Management level</u>	<u>Execution time/</u> (Minutes)
63	Volume	90	9	Extensive	2.31
30	Volume	90	9	Intensive	2.93
8	Area	80	8	Extensive	23
63	Area	100	10	Extensive	.57
63	Mixed	100	10	Extensive	1.50

^{1/} Does not include compilation time. Time is for version 9, modification level 11, of the IBM 7040 Operating System. Also, SORAC is operational on the IBM 360/50 and CDC 6400 computing systems.

AVAILABILITY OF SORAC

Requests for the "User's Manual for SORAC Computer Program" (including source program listing) and FORTRAN IV source deck may be addressed to the Director, Pacific Northwest Forest and Range Experiment Station, P.O. Box 3141, Portland, Oregon 97208.

Pacific
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Forest Service **RESEARCH NOTE**

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EFFECTS OF PROTECTION FROM DEER
ON SURVIVAL AND GROWTH
OF DOUGLAS-FIR SEEDLINGS

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ABSTRACT

Protection from deer had little effect on survival of planted and natural Douglas-fir seedlings after eight growing seasons. Protected trees were slightly taller than unprotected trees. Trees from natural seedfall were taller than planted trees. Unprotected planted stock was shorter than its protected counterpart and showed no sign of "catching up." This difference should be of little consequence after a cutting cycle.

Animal injuries to Douglas-fir (*Pseudotsuga menziesii*) seedlings lengthen establishment intervals in many plantations in the Pacific Northwest. Ranking high in causing injuries are black-tailed deer (*Odocoileus hemionus columbianus*). Deer browse leaders of seedlings until they are 4 or 5 feet high and feed on laterals of taller trees.

It is not known whether browsed and shortened seedlings eventually "catch up" with their unbrowsed neighbors because long-term studies under various site conditions have not been made.

^{1/} Estacada Ranger District, Mount Hood National Forest, Portland, Oreg. Present address: Wenatchee National Forest, Wenatchee, Wash.

Opportunities to evaluate browsing effects are relatively rare. Mitchell^{2/} studied short-term effects of animal feeding on Vancouver Island, but older, long-term research studies usually did not include measures of browsing incidence or intensity. More recent studies have not been in progress long enough for meaningful results.

THE STUDY

The study was begun in 1958 by the Estacada Ranger District of the Mount Hood National Forest to determine effects of deer browsing on survival and growth of Douglas-fir seedlings. The study site was located on a moderate, northwest-facing slope, at an elevation of 1,600 feet in the Fish Creek drainage of the Clackamas River, about 40 miles southeast of Portland, Oregon. Resident deer occupy the lower Fish Creek drainage which also provides winter range for animals that summer at higher elevations. Thus, it was believed that seedlings growing there would be subjected to intensive deer browsing.

A 250- to 300-year-old stand of Douglas-fir with western hemlock (*Tsuga heterophylla*) was harvested from the low site III land in 1950. Slash was burned, and the area was subsequently reburned in 1956 by a fire which escaped during slash disposal on an adjacent unit.

Soils are derived from basalt, and vegetation is typical of lower elevation cutover forest land in the west-central Cascade Range in northern Oregon. Major woody species in 1967 included *Prunus emarginata*, *Ribes* spp., *Rubus ursinus*, *R. leucodermis*, and *Alnus rubra*. Many species of forbs and grasses were also present in the vegetative mantle.

METHODS

A square, 1-acre, deer-tight enclosure was built on an area planted with 2-0 seedlings in winter 1958-59. A scattered stocking of similar-sized natural Douglas-fir on the site permitted comparison of browsing effects on planted and natural seedlings.

A sample of 75 seedlings, 25 natural and 50 planted, was randomly selected inside and outside the enclosure. Sample trees were permanently marked and their locations plotted with compass and chain to permit subsequent relocation.

^{2/} Mitchell, K. J. Height growth losses due to animal feeding in Douglas fir plantations, Vancouver Island, B. C. Forest. Chron. 40: 298-307, illus. 1964.

Initial height measurements were made at the time of sample selections. Annual examinations were begun in April 1960 just before bud burst and continued through 1967.

RESULTS AND DISCUSSION

Although the study objective was to determine effects of deer browsing, it was soon evident that clipping by snowshoe hare (*Lepus americanus*) or brush rabbits (*Sylvilagus bachmani*) also occurred. Seedlings both inside and outside the exclosure were clipped during the first 2 and last 2 years. Terminals of a few protected seedlings were clipped within the first 2 years. Although not recorded, it is likely that a similar number was clipped on unprotected seedlings. Thus, with clipping effects presumably equalized, differences in survival and height growth can be attributed to browsing by deer.

The chronological animal feeding pattern is shown in figure 1.

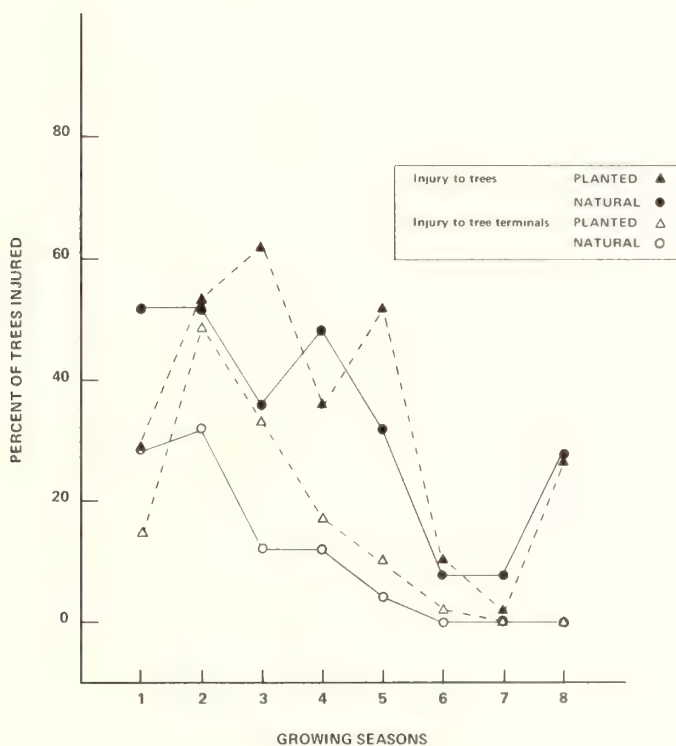


Figure 1.--Incidence of injuries to unprotected Douglas-fir trees.

After the first 2 years, percentages of terminal shoots injured were considerably lower than percentages of browsing or clipping on any part of the tree. Terminal injuries were actually much lower than had been expected prior to the establishment of the study. A "t" test revealed no significant difference in animal choice ($p = 0.05$) between planted and natural seedlings through the 8-year inspection period.

Through 1966, the seventh year, injuries showed a general decline (fig. 1). The upturn in 1967 was all due to minor clipping of lower laterals. Even inside the exclosure, 28 percent of all trees exhibited similar lateral clipping in 1966. The proportion clipped inside soared to 86 percent in 1967 but had negligible effect on the trees, most of which were 6 feet or more in height. The recent increase in clipping may have been associated with the progressive annual improvement of hare and rabbit habitat, especially inside the exclosure where protection from deer resulted in a dense canopy of woody and herbaceous plants. Nearly all clipping of protected and unprotected trees occurred from 2 , to 4 feet above ground level, indicating that it took place when snow cover was present.

Figure 2 shows that survival of natural seedlings was higher than planted stock. This was expected because the naturals were in place and growing well when the nursery stock was planted. Survival of planted stock was also high with 80 percent of all planted trees alive after eight growing seasons.

Protection from deer had little effect on seedling survival. Seven of the 20 trees that died were browsed or clipped. Four of these were inside and three outside the exclosure.

Results of annual height measurements are illustrated in figure 3. First measurements indicated that heights were similar among natural and planted seedlings, inside and outside the exclosure. Height differences observed by the second year tended to persist or increase through the study period.

Comparison by analysis of variance indicated that, after eight growing seasons, natural trees at 10.5 feet were significantly taller ($p = 0.01$) than planted trees (6.7 feet). Trees inside the exclosure averaged 8.9 feet and were significantly taller ($p = 0.05$) than those without protection which averaged 7.4 feet in height. Close inspection of figure 3 suggests that unprotected seedlings were not "catching up" with their protected counterparts, even though terminal and all but incidental lateral browsing and clipping had ended 3 years earlier.

Although sample sizes were relatively small, results in figure 4 show that injuries to terminals depressed height growth and that repeated terminal injuries caused progressively greater height losses.

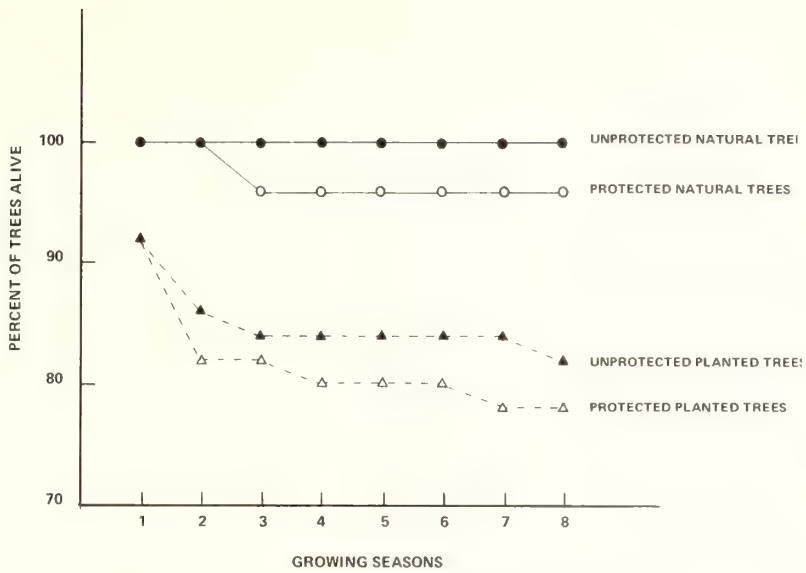


Figure 2.--Survival of protected and unprotected Douglas-fir trees.

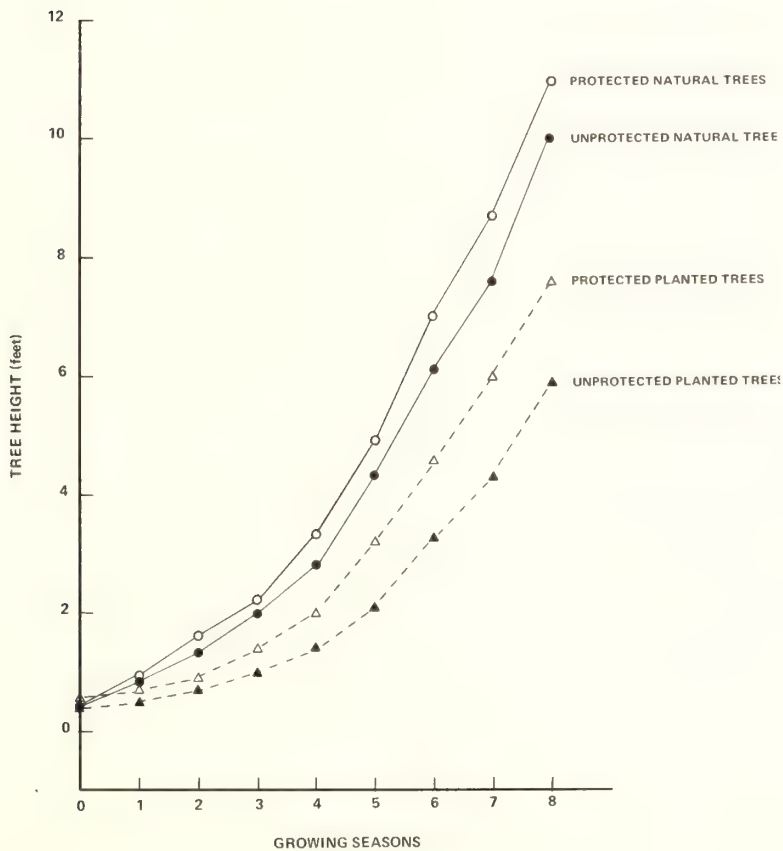


Figure 3.--Heights of protected and unprotected Douglas-fir trees.

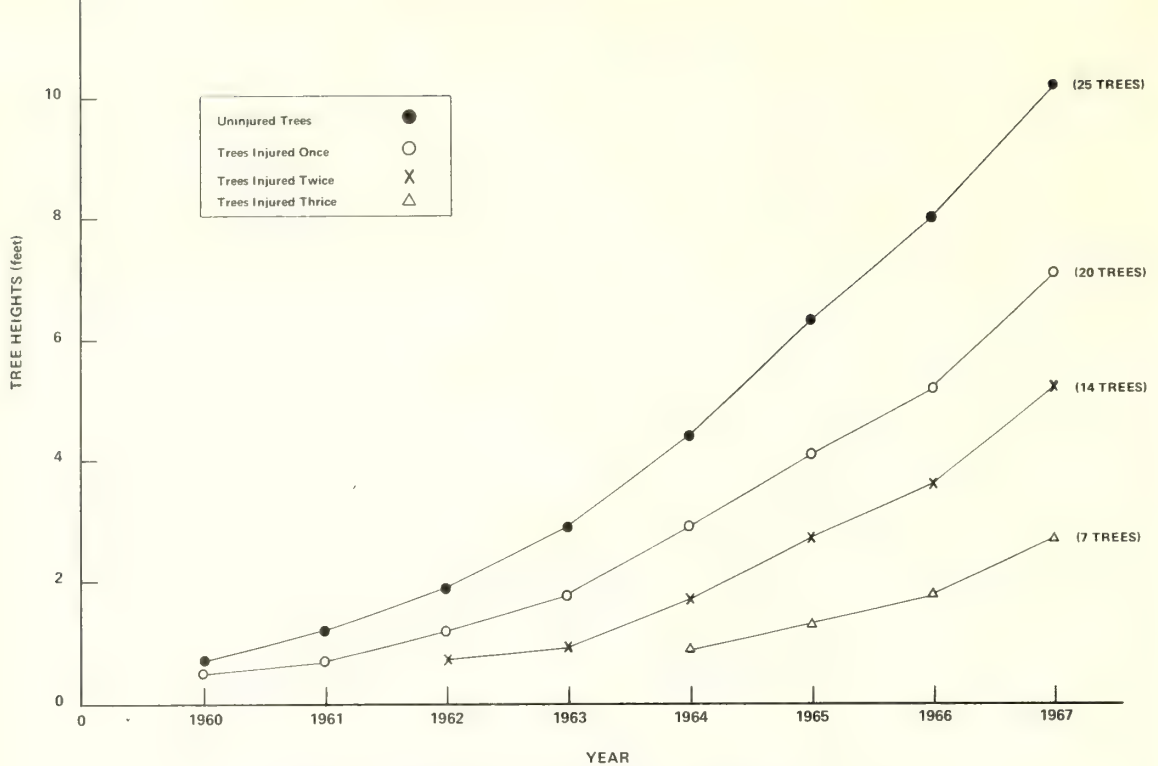


Figure 4.--Effects of terminal injuries on height growth of all unprotected Douglas-fir trees.

There is little doubt that browsing suppressed height growth of planted and natural trees. Damaging injuries, those which removed leaders, occurred through the first 5 years of the study. Trees free from leader damage for 3 additional years, although growing reasonably well, showed little signs of attaining the height of their unbrowsed neighbors.

Referring again to figure 3, one can see that the greatest comparable height difference after eight growing seasons separates protected and unprotected planted trees. This difference amounted to only 1.7 feet. If unprotected trees never catch up but continue to grow as rapidly as unbrowsed trees, the early browsing they sustained should be of little consequence after a 60- or 100-year-cutting cycle.

Probably the most important lesson to be learned from this study is that deer browsing on new seedlings does not necessarily signal a reforestation disaster. On the other hand, only constant field observation by local managers will provide the information needed to delineate those areas where browsing is likely to cause intolerable losses of productivity.

PNW-95

January 1969

A DIGITAL TEMPERATURE MONITOR FOR PHOTORECORDING

by

William B. Fowler, *Meteorologist*



ABSTRACT

A method of digitizing atmospheric measurements for portrayal with a time-lapse camera is described. A servomechanism rebalances a resistance bridge which has the temperature sensor as an active component. A mechanically coupled encoder determines the proper combination of relay closures which, in turn, causes the temperature to be projected by means of a light bank.

During a recent study of rime accumulation in high-elevation lodgepole pine stands, an unattended time-lapse camera provided the main record. Air and dewpoint temperatures were included in the photorecord to assist in the analysis of the riming events as they appeared in the photos. Pictures were taken at 6-minute intervals during daylight hours. Film was retrieved monthly and subsequently analyzed.

Several methods of including data in the photorecord were considered. The simplest method would require exposing a series of large dials representing the analogs of the atmospheric measurements. Although this has the advantage of simplicity, several disadvantages precluded its use here. These were low resolution at times of poor visibility or during inclement weather (snow or ice coating the dials for lengthy periods), low-temperature failure of mechanical components, difficulties of separation of sensor and dial output, and restrictive input signals.

The system used has considerable flexibility regarding sensor location and measurement portrayed on the light banks. Although this

paper describes the system's use only as a temperature monitor (eventually including air, dewpoint, and soil surface temperatures), at times maximum windspeed and cumulative windrun were also included. Under moderate coatings of ice and snow, lights remained readable; however, under infrequent extreme conditions, loss of record did occur. Readout was obviously most legible at times of low ambient light. This was an additional advantage, since at low light levels, depth of field was restricted due to large camera aperture. For this reason, light banks were positioned near the primary focal distance (40-50 feet) where depth-of-field changes would have little effect on legibility.

Air and dewpoint temperatures were measured with similar resistance thermometers. The dewpoint (or frost point) was derived from the temperature of a thermoelectrically cooled, mirrored surface. Air temperature was measured in a suitably shielded enclosure.

The main elements in the system (figs. 1, 2, and 3) are:

1. resistance bridge network,
2. servoamplifier and motor,
3. encoder,
4. relay tree, and
5. light bank.

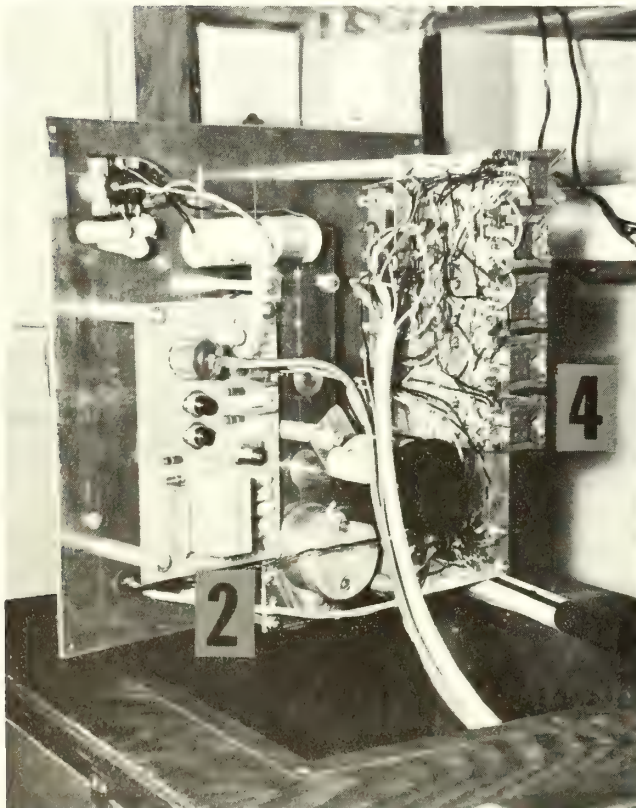


Figure 1.--Amplifier and rebalancing motor (2); relay tree (4). Numbers correspond to text description.

**Figure 2.--Side view; note indentation on
code disks (3).**

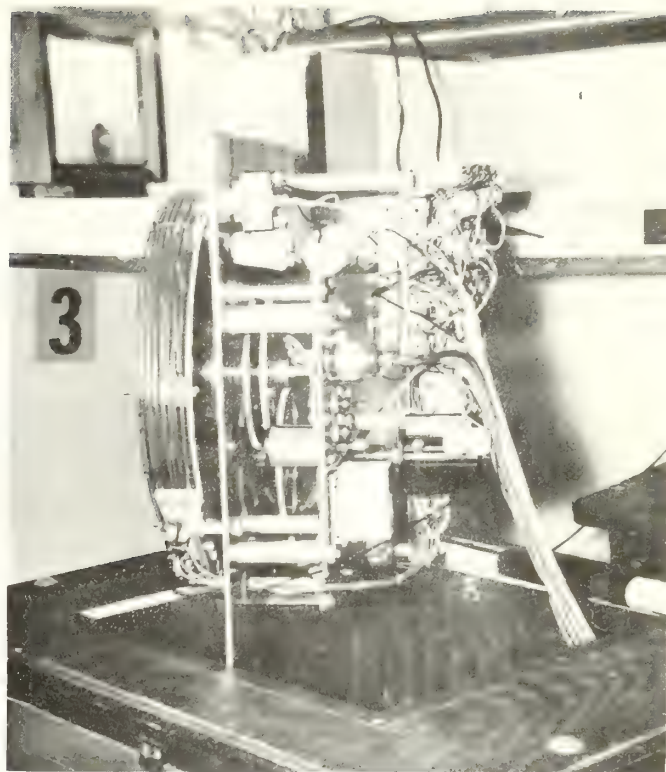
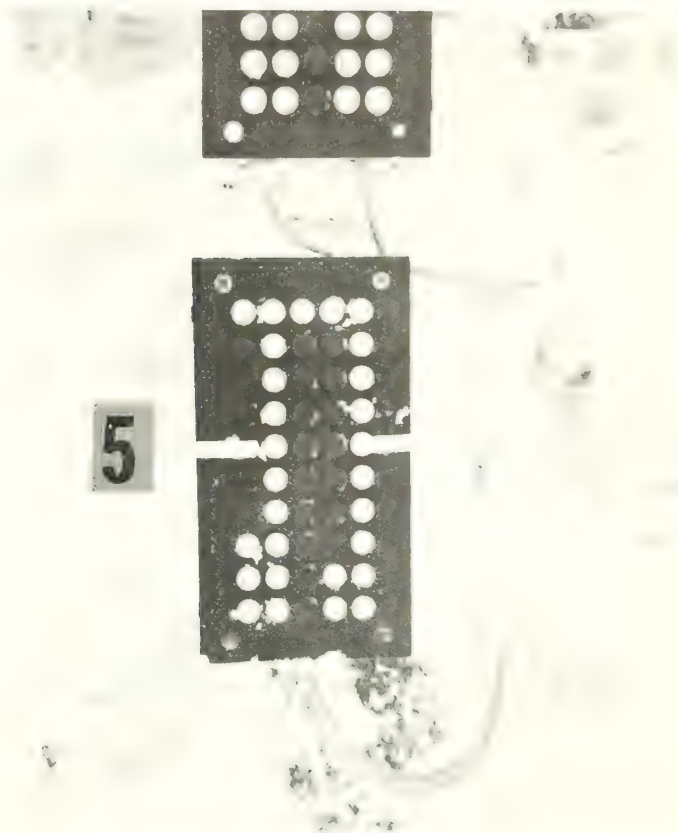
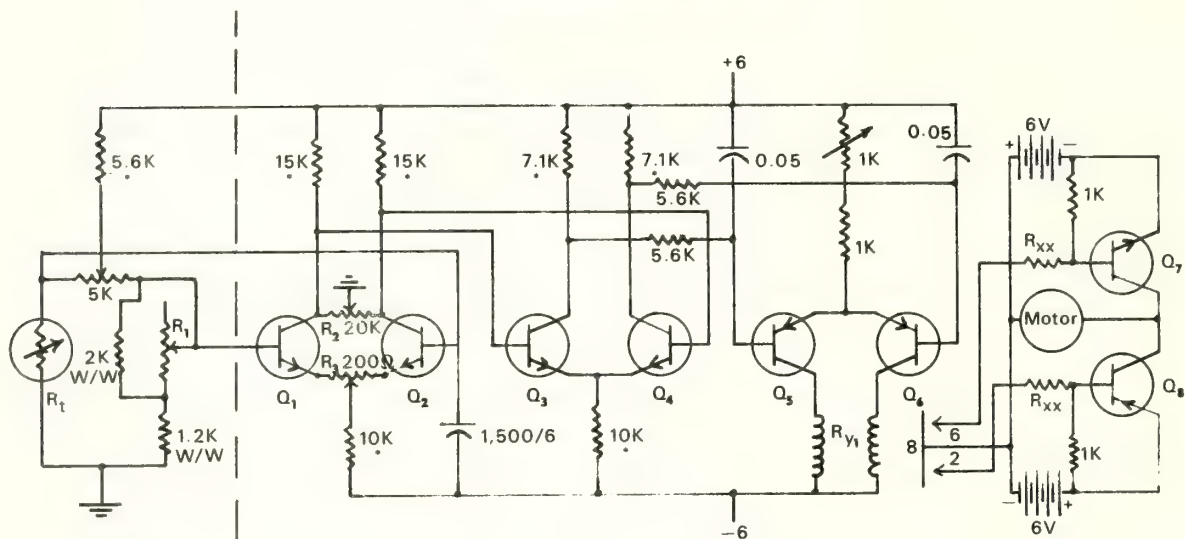


**Figure 3.--Light bank; temperature indication
is -11°C .**



The resistance bridge (fig. 4) has two variable components--the temperature sensor and the rebalancing potentiometer. If sensor and balance potentiometer are of equal resistance, the system is stable; the servomechanism notes out-of-balance conditions and corrects them by driving the potentiometer in the proper direction to rebalance the system.

Figure 4.--Schematic drawing of servoamplifier, resistance bridge, and motor control.



Resistance bridge

Amplifier

Q₁-Q₄: 2N 338
Q₅, Q₆: 2N 414
Q₇: 2N 1308
Q₈: 2N 1309

R₁: 1,000 ohms, 10 turns
R_y: Micropositioner relay, AYLZ H 4013S
R_t: Microsensor, type TE3A-C1-2000
R_{xx}: Nominal, 3,000 ohms, chosen for adequate base drive

Motor: Haydon, No. H5309 6VDC, 10 r.p.m.
Note: * = ¼ W 1 percent film
W/W = ½ W 1 percent wirewound
Otherwise ½ W 5 percent carbon

The servoamplifier^{1/ 2/} has three stages of amplification driving a sensitive differential relay. If the bridge is unbalanced, relay contacts 2 and 8 or 6 and 8 close, providing base current to the motor control transistors. PNP and NPN transistors with a center-tapped supply provide the proper motor shaft rotation for rebalancing the resistance bridge. Use of low-grain differential stages reduces temperature effects on amplifier operation. Transistors Q₁ and Q₂ are mounted in an aluminum block to equalize temperature drift. These transistors were matched over the range of 0° to 20° C. by cooling the mounting block. Variable resistances R₂ and R₃ were adjusted during this cycling

^{1/} Carroll, J. M. Transistor circuits and applications. 283 pp., illus. New York: McGraw-Hill Book Co., Inc. 1957.

^{2/} Turner, L. P. Handbook of semiconductor electronics. 664 pp., illus. New York: McGraw-Hill Book Co., Inc. 1962.

to reduce any residual transistor differences. Reduction of temperature effects over this range to an equivalent error of less than $\pm 0.25^\circ \text{C}$. was easily accomplished in the two instruments constructed. The dead band of the system amounts to approximately 4 ohms or $\pm 0.25^\circ \text{C}$. over the temperature range measured. Change of the sensor resistance of less than this amount does not initiate rebalancing. Since the encoding is done on a 1°C . basis, this resolution is quite sufficient

The reversible d.c. motor, in addition to electrically rebalancing the system, changes the position of the encoding disks coupled to the potentiometer shaft. Each of the disks controls a level of the relay tree through a perimeter-mounted microswitch. An additional microswitch is operated as the disks rotate through 0°C . to indicate polarity.

Disks were indented with the proper switching patterns after locations had been determined through calibration with a resistance decade box. Switchpoints were chosen as midway between 1° temperature locations on the disks. Code 0 was indexed by removal of material causing the normally closed contact to be closed. Code 1 closes the normally open contact.

The code 3/ 4/ 5/ used for the disks (table 1) reduces encoding errors by restricting each degree change to a single-level change in the code. Since the temperature range is balanced fairly well around the zero point and of limited range, the code is well suited to this system. Temperature measurements cover the range of $+16^\circ$ to -29°C .

The relay tree (fig. 5) sets the relay contacts to form digital combinations based on coded information from the shaft encoder. Level 1 is a directly controlled microswitch and requires no corresponding relay in the relay tree. It is designated as S_1 . Relays R_{y2} to R_{y6} are operated by microswitch closures and correspond to code levels 2 to 6, respectively. Interrogation of this tree from left to right drives the appropriate lights. Lights are located in a two-decade configuration (00-99) with 9 in the tens decade used for polarity indications.

An additional control system establishes camera frame timing and interrogates the code disks and the relay tree. The shutter release

3/ Griffin, D. P. Disk encoder design avoids ambiguities. Electronics 33(17): 62-66, illus. 1960.

4/ Walston, J. A., and Miller, J. R. Transistor circuit design. 523 pp., illus. New York: McGraw-Hill Book Co., Inc. 1963.

5/ Wasserman, R., and Nutting, W. Solid state digital code to code converter. Electronics 32(50): 60-63, illus. 1959.

Table 1.--Cyclic code used in shaft position to temperature encoder

Temperature (degrees centigrade)	Code level 1 2 3 4 5 6	Temperature (degrees centigrade)	Code level 1 2 3 4 5 6
0	0 0 1 0 1 0	15	1 0 1 1 0 0
1	0 0 1 1 1 0	16	1 0 1 1 0 1
2	0 0 1 1 1 1	17	1 0 1 1 1 1
3	0 0 1 1 0 1	18	1 0 1 1 1 0
4	0 0 1 1 0 0	19	1 0 1 0 1 0
5	0 0 0 1 0 0	20	1 1 1 0 1 0
6	0 0 0 1 0 1	21	1 1 1 1 1 0
7	0 0 0 1 1 1	22	1 1 1 1 1 1
8	0 0 0 1 1 0	23	1 1 1 1 0 1
9	0 0 0 0 1 0	24	1 1 1 1 0 0
10	1 0 0 0 1 0	25	1 1 0 1 0 0
11	1 0 0 1 1 0	26	1 1 0 1 0 1
12	1 0 0 1 1 1	27	1 1 0 1 1 1
13	1 0 0 1 0 1	28	1 1 0 1 1 0
14	1 0 0 1 0 0	29	1 1 0 0 1 0

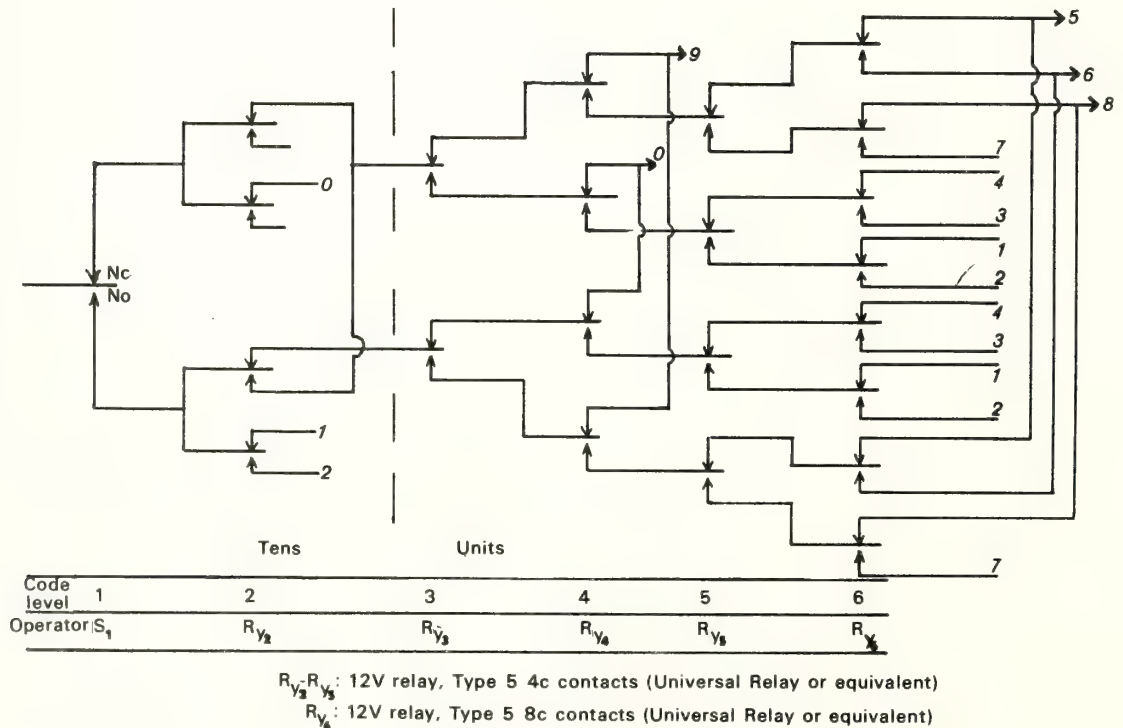


Figure 5.--Relay tree.

is delayed to allow lights to reach full brilliance. The No. 1829 bulbs provide adequate images at a distance of 40 feet. Relays and lights operate only during camera frames to conserve battery power.

This system was designed to operate unattended and in a remote location with minimum drain on the battery supplies. Available components were used with reliability and ease of servicing preferred over compactness. The original two systems are in their second year of operation. The single operational failure thus far was due to a faulty contact in variable resistor R_1 . Some economies could be effected by use of an encoding disk constructed with alternate conductive and insulated segments; however, because of possibility of contamination of these sliding contacts, the microswitches were used. A number of commercially available operational amplifiers may be substituted for the amplifier described here if desired.

Pacific
North
West Forest and Range Experiment Station
U.S. Forest Service **RESEARCH NOTE**

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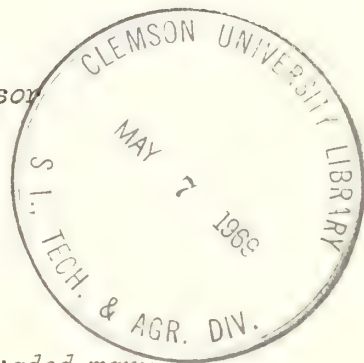
THE MARKETING OF RED ALDER PULPWOOD AND SAW LOGS

by

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Department of Resource Development
Michigan State University

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ABSTRACT

In the Pacific Northwest, red alder has invaded many cutover areas which once supported Douglas-fir. As the supply of red alder increased, more uses were found and red alder became more valuable. This Note measures the present red alder resource and summarizes its production, marketing, and future prospects.

Introduction

For many years, the old-growth Douglas-fir forests of the Pacific Northwest have been a major source of the Nation's timber supply. Since the end of World War II, efforts to renew these forests for a second crop of timber have been made on a significant scale in western Oregon and Washington. Many times, however, large areas of cutover land which once supported valuable stands of Douglas-fir had been invaded by less desirable species, principally red alder (*Alnus rubra*). Now, many forest managers are faced with deciding whether to manage alder or to convert those areas back to conifer production (the research staff in Production Economics at the Pacific Northwest Forest and Range Experiment Station is currently preparing economic guidelines to assist in these decisions). As background for this decision, this Note measures the extent of the problem and briefly describes the production and marketing of red alder.

Area and Volume of Alder Have
Increased Considerably
Since 1930's

Because it quickly becomes established under most conditions where mineral soil has been exposed by logging or fire, the red alder forest type has frequently replaced Douglas-fir, Sitka spruce, and western hemlock in the Douglas-fir subregion (Worthington et al. 1962). The results of a recent study based on 1931-33 survey standards--to account for changes in forest type definitions and survey techniques--suggest that the area in western Oregon in commercial hardwood types increased nearly fourfold in the last 35 years and is now 37-percent red alder. Even more spectacularly, in southwestern Washington, the area in commercial hardwood types increased sevenfold and is now 81-percent red alder. Today, about 2-1/2 million acres are in the red alder type (U.S.D.A. Forest Service 1965).

Over three-fourths of this red alder type is privately owned in western Oregon and western Washington, which reflects both the location of these stands and the history of their early cutting. However, only about two-thirds of the total regional growing-stock volume is on private lands.

Volume of red alder increased slowly from the early thirties to World War II and quite markedly from then on. Red alder sawtimber volume nearly doubled between 1953 and 1963 and made up nearly 60 percent of the total hardwood sawtimber volume but less than 3 percent of all sawtimber volume in the Douglas-fir subregion in 1963 (U.S.D.A. Forest Service 1958, Metcalf 1965). Although such figures might well have been influenced by changes in estimating techniques, this sharp rise must be presumed to be largely real.

The increase in the supply of merchantable red alder generated new uses for the species which increased its value. In turn, this opened a whole series of new and economically desirable opportunities in forest land management. Thus, evaluating the present and possible production techniques and markets for this species is a major concern of the forest manager.

Red Alder Timber Production Less
Orderly Than Conifer Production

Unlike softwoods, red alder stumpage is not usually purchased directly by the primary manufacturer to be logged later by company crews or by a logging contractor. Instead, it is purchased by small-scale operators who switch back and forth between hardwood logging and softwood logging, relogging, and thinning. Part-time farmers produce most of the pulpwood with light, farm-type equipment, usually from their own or other nearby private lands. Both the farmers and small logging

operators switch to hardwoods more often because their primary activities become unprofitable or unseasonal than in response to any economic advantages for operating in hardwoods (Grobey 1964).

The preponderance of these relatively inefficient operators in alder logging has contributed to historically high logging costs for the industry. In addition, experience gained by the U.S. Forest Service Forestry Sciences Laboratory at Olympia, Washington, indicates that pulpwood logging costs for alder and Douglas-fir are about equal; but when it comes to logging for sawtimber, the operator can earn about 10 percent more per unit of time in Douglas-fir. The difference is due primarily to the added care that must be taken with alder, particularly the care required to prevent log breakage and splitting in felling operations.

Hardwood mill operators purchase stumpage and contract the logging more commonly now than in the past. This has encouraged some loggers to concentrate full time on red alder logging. Concurrently, there has been a trend toward larger sales of hardwood stumpage, particularly from public lands. Probably this change in sales policy has been both a cause and effect with respect to the trend in stumpage purchase policies of processors.

Stumpage Prices for Red Alder Vary Considerably

Information concerning stumpage prices for red alder or other hardwoods that grow in the Pacific Northwest is not as readily available as it is for softwoods. Until recently, there have been few strictly alder sales, particularly from public lands. When alder stumpage prices have been quoted, they have seldom been indicative of true market prices since, as a minor component of the sale, they have usually been somewhat arbitrarily estimated and the main concern has centered around Douglas-fir or other conifers. On the basis of informal observations, we estimate the ranges for red alder pulpwood and sawtimber to be, respectively, \$1.50 to \$7.50 per cord and \$4.00 to \$21.00 per thousand board feet.

Delivered Prices

Delivered prices for alder saw logs and pulpwood, on the other hand, have been reported for several years by the Oregon and Washington Agricultural Extension Services as well as by the Washington Department of Natural Resources. Saw-log prices have been running about \$43 per thousand board feet but have ranged between \$35 and \$48 per thousand. These prices vary considerably from one locality to another and are directly related to the number of purchases and the milling capacity of the particular sale area. In 1962, median prices differed between localities in Washington by as much as \$17 per thousand board feet, which appears to be more variation than can be explained by differences in factors such as grade and size (Grobey 1964). Saw-log prices reached a relative plateau by 1959 and rose only moderately between then and 1962 when another upward surge occurred. In comparison with Douglas-fir, however, sizable annual fluctuations have characterized alder saw-log prices.

Prices for delivered red alder pulpwood, in contrast to saw-log prices, have varied little from one mill to another or from one locality to another. For the Pacific Northwest as a whole, they averaged about \$14.50 per cord and ranged from \$13.50 to \$17. Grobey (1964) observed that pulpwood prices in western Washington varied directly with the distance to the mill and that they were little influenced by other factors. He felt this was due both to the uniformity of quality in alder pulpwood from one cord to the next--which is in sharp contrast to the alder saw-log situation--and to the ability of the relatively few mills purchasing alder pulpwood to effectively administer the prices they paid. Alder pulpwood prices have been quite stable over time and have been characterized by no discernible trend in recent years.

Red Alder Output Has Been Increasing

The output of red alder from the forests of western Oregon and Washington has been increasing rapidly since the early fifties. Total output is now estimated at over 80 million board feet of saw logs and over a half-million cords of pulpwood (table 1). Minor quantities are also utilized for fuelwood, posts, and veneer logs.

Between 1953 and 1964, saw-log output increased seven times and pulpwood eight times. In terms of cubic volume, pulpwood has been the more important product for about 15 years. As a group, the minor products have declined. Veneer logs are an exception: although still insignificant in the total product mix, they appear to be increasing in importance.

The physical properties of red alder are generally desirable for lumber production. Although few accurate statistics are available, one study (Gill 1965) estimated that 93 percent of red alder lumber found its way into the furniture and fixtures industry in 1960. Another study (Bloch and Associates 1964) suggested that, although red alder contributes less than 1 percent to the total of all U.S. hardwood lumber production, a group of species with properties similar to red alder made up about one-third of that volume in 1962.^{1/}

The rapidly increasing rate of consumption of red alder pulpwood by the woodpulp industry of the Pacific Northwest speaks for itself as to the suitability of this species as a raw material for this industry. Though the commercial pulping of this species has a relatively short history, Grobey (1964) estimated that nine out of the 17 pulpmills in

^{1/} Maple, birch, beech, and the gums were included as species with physical properties similar to red alder, but, for some unknown reason, yellow poplar was omitted from this group.

Table 1.--*Estimated output of red alder in western Oregon and Washington, by major timber product group, 1951-65*^{1/}

Year	Saw logs	Pulpwood ^{2/}	Fuelwood
	<u>M bd. ft.</u>	- - - - - <u>Cords</u> - - - - -	
1951	10,000	^{3/} 11,000	6,200
1952	11,000	^{3/} 31,000	5,300
1953	11,000	64,000	5,000
1954	18,800	98,000	5,100
1955	21,000	137,000	5,100
1956	33,000	175,000	4,100
1957	29,000	211,000	3,600
1958	31,000	226,000	3,600
1959	43,000	259,000	3,400
1960	47,000	295,000	3,300
1961	48,000	342,000	2,400
1962	48,000	381,000	(^{5/})
1963	66,000	462,000	(^{5/})
1964	^{4/} 79,000	518,000	(^{5/})
1965	82,000	(^{5/})	(^{5/})

^{1/} Estimated by the authors on the basis of:

- a. Data available from unpublished sources,
- b. U.S. Bureau of the Census' Current Industrial Reports,
- c. Western Wood Products Association's Statistical Year Book,
- d. State of Washington Department of Natural Resources annual timber harvest reports, and
- e. Other miscellaneous published sources.

^{2/} Includes a small amount of mill residues.

^{3/} Does not include estimates for Oregon.

^{4/} Ivan Bloch and Associates estimated in 1964 that the market for red alder lumber was from 120 million to 140 million board feet annually, thus indicating the estimates shown here are on the conservative side.

^{5/} Not available.

western Washington were pulping local hardwoods, mostly alder. Seven of these mills were judged to be using substantial quantities of alder. Although pulpwood users compete with the lumber industry for alder, they also provide a ready market for low-grade lumber materials that might be undesirable at a particular time.

Most alder is being pulped by the standard sulfate and sulfite processes, but a portion is being manufactured by the relatively new neutral sulfite semichemical process (Worthington et al. 1962). It has also been demonstrated that it is feasible to pulp red alder by the conventional mechanical processes plus the groundwood and chemigroundwood processes. Because certain final products are improved when a soft hardwood such as red alder is added to a softwood pulp, hardwood pulp will probably be regarded in the future as an essential--as well as an available and inexpensive--ingredient for papermaking.

The Market Outlook for Red Alder Is Bright

Future markets for red alder logs and stumpage will depend on how the final products manufactured from lumber and woodpulp fare in broader national and world markets.

The paper products and dry pulp (including dissolving pulps) produced in western Oregon and Washington, wholly or partially from red alder, are in direct competition with similar products from throughout the world. There is a relative advantage in transportation costs from the Pacific Northwest to the areas of rapidly growing consumption on the west coast.

We can anticipate expanding markets for pulp and paper products in the entire Pacific Rim. Vigorous competition can be expected from other regions and other countries during the next decade or two, but a significant share of these markets will still be served by pulp and paper products containing red alder. In the subsequent 10- to 20-year period, however, competition may be expected to increase in the Pacific Rim as other nations in a position to serve the area develop their pulping capacities.

The outlook for red alder lumber markets appears a little less certain, but the potential for market expansion and earnings may be even greater than for alder's use for pulp and paper products. At the present time, it is estimated that about half of all red alder lumber production finds its way into California markets--most of it eventually going into the rapidly developing southern California furniture industry. Here, alder encounters stiff price competition from eastern hardwoods which have been the traditional source of supply for the whole furniture industry. Fragmentary evidence indicates that, in the past, California buyers of alder have vacillated between it and eastern woods

as small shifts have occurred in the delicately balanced price ratios between the two sources of lumber, with tropical hardwoods remaining a distinct threat.

There have been recent increases in the prices of eastern hardwoods and improvements in the organization of hardwood marketing in the Pacific Northwest. As a result, the alder lumber and wood products industry has stabilized; this, along with the continuing high rate of economic growth throughout the west coast, makes the outlook quite promising. Prospects for successful invasion of markets farther east or of the international markets of the Pacific Rim, however, appear quite unlikely. In the case of the latter markets, locally grown hardwoods are plentiful and have a definite price advantage. In fact, alder lumber is likely to encounter increased competition from foreign hardwoods throughout its current marketing area, even including the west coast. This suggests that the red alder lumber industry should continue to work toward a goal of price stabilization by insuring a more dependable supply of its members' products.

LITERATURE CITATIONS

Bloch, Ivan, and Associates.

1964. Western markets for red alder from specified counties in Oregon and Washington. U.S. Dep. Com., Area Redevelopment Admin., Washington, D.C., 56 pp.

Gill, Thomas G.

1965. Wood used in manufacturing industries. Forest Service, U.S. Dep. Agr. Stat. Bull. 353, 121 pp.

Grobey, John H.

1964. An economic analysis of the hardwood industry of western Washington. Wash. State Dep. Com. and Develop., 101 pp.

Metcalf, Melvin E.

1965. Hardwood timber resources of the Douglas-fir subregion. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Resource Bull. PNW-11, 12 pp.

U.S.D.A. Forest Service.

1958. Timber resources in America's Future. U.S. Government Printing Office, Washington, D.C., 713 pp.

1965. Timber resource statistics for the Pacific Northwest as of January 1, 1963. Pacific Northwest Forest & Range Exp. Sta. Resource Bull. PNW-9, 38 pp.

Worthington, Norman P., Ruth, Robert H., and Matson, Elmer E.

1962. Red alder; its management and utilization. U.S. Dep. Agr. Misc. Pub. 881, 44 pp., illus.

Pacific
North
West Forest and Range Experiment Station
U.S. Forest Service **RESEARCH NOTE**

PNW-97

February 1969

CHARTS FOR DETERMINING SAMPLING RATE AND NUMBER IN SAMPLE

by

David Bruce, *Principal Mensurationist*



ABSTRACT

Four charts are presented that show sampling rate and number in sample for different desired levels of accuracy when number in population and coefficient of variation can be estimated.

Sampling is replacing both complete enumeration and complete measurement in many phases of forestry work. Calculation of sampling rate or number in sample for a given level of sampling accuracy when number in entire population and coefficient of variation are known or can be estimated is a frequently recurring arithmetic exercise. This requires a preliminary estimate of number in sample to find an appropriate value of Student's "t" to use in the calculation. If this estimate is too far from calculated value when sample is small, the calculation should be repeated. However, the calculation can be avoided by use of charts like those presented in this note.

The following charts were prepared as an aid in sample scaling but are applicable to many other sampling problems. Each chart is for a different level of desired accuracy (E) from 1 to 4 percent. Accuracy is percentage difference between the sample estimated mean or

total and the population value. If sampling rate is based on figure 2, it can be stated that this difference or desired accuracy (E) will not exceed 2 percent. Statements like this have a 95-percent probability of being correct.

To use these charts for sample scaling, first select a level of desired accuracy (E) and estimate the total number of truckloads (N) in the sale and the coefficient of variation (CV) among truckload scales. For example: assume 2-percent desired accuracy, 2,000 truckloads, and 15-percent coefficient of variation. Use figure 2, find 2,000 on bottom scale and 15 percent on right margin. Follow 15-percent curve to left until it intersects vertical line 2,000. From this intersection, go horizontally to left margin and read $n = 195$ as required sample size, or read next higher diagonal line above the intersection to get a sampling rate of 1 in 10 loads.

Note: These charts solve the equation

$$n = \frac{1}{\frac{1}{N} + \frac{E}{2Ct}}$$

where

n = number in sample

N = number in population

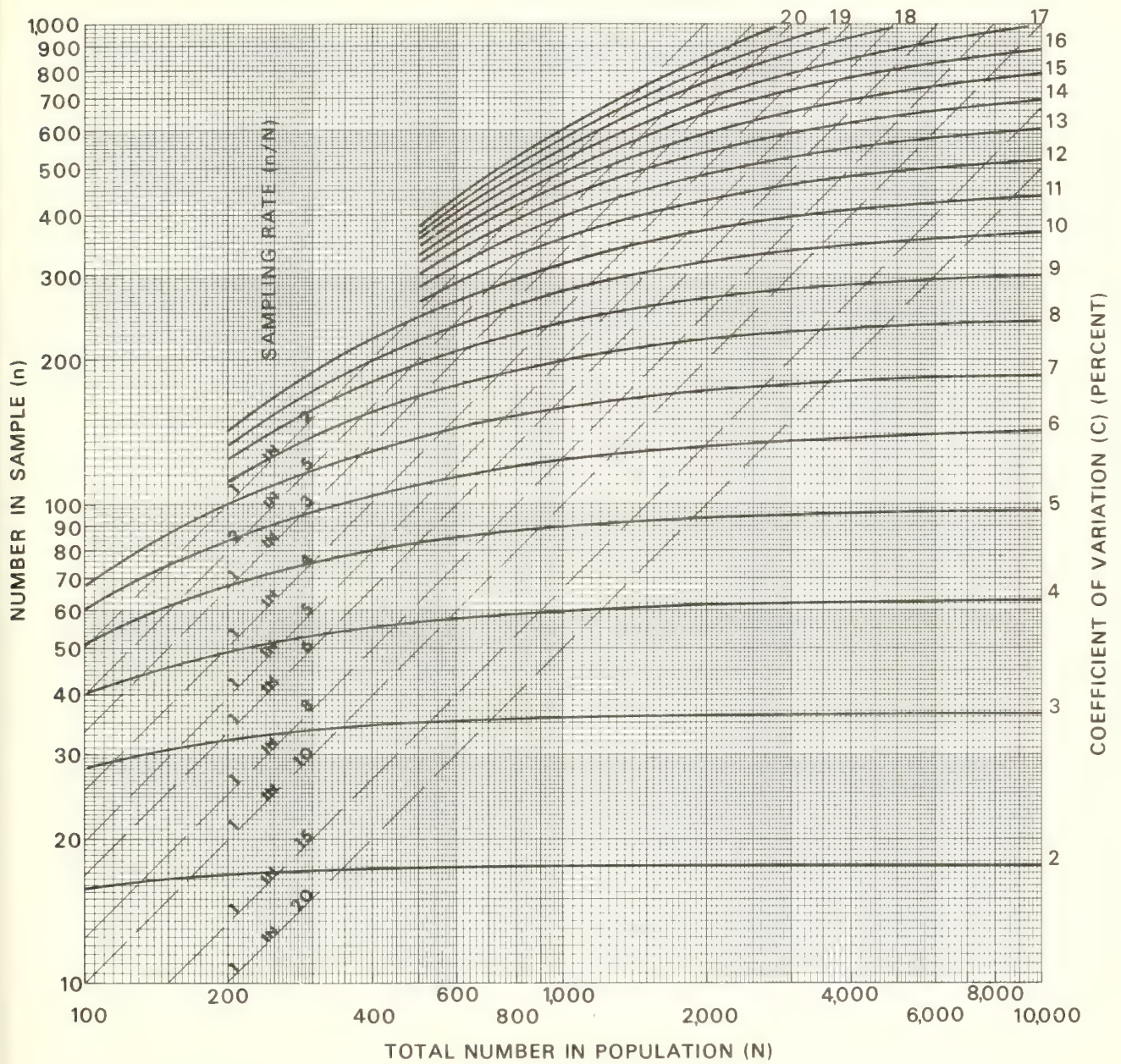
E = desired accuracy in percent

C = coefficient of variation of sample units in percent

t = tabular value of Student's "t" with $(n-1)$ degrees
of freedom

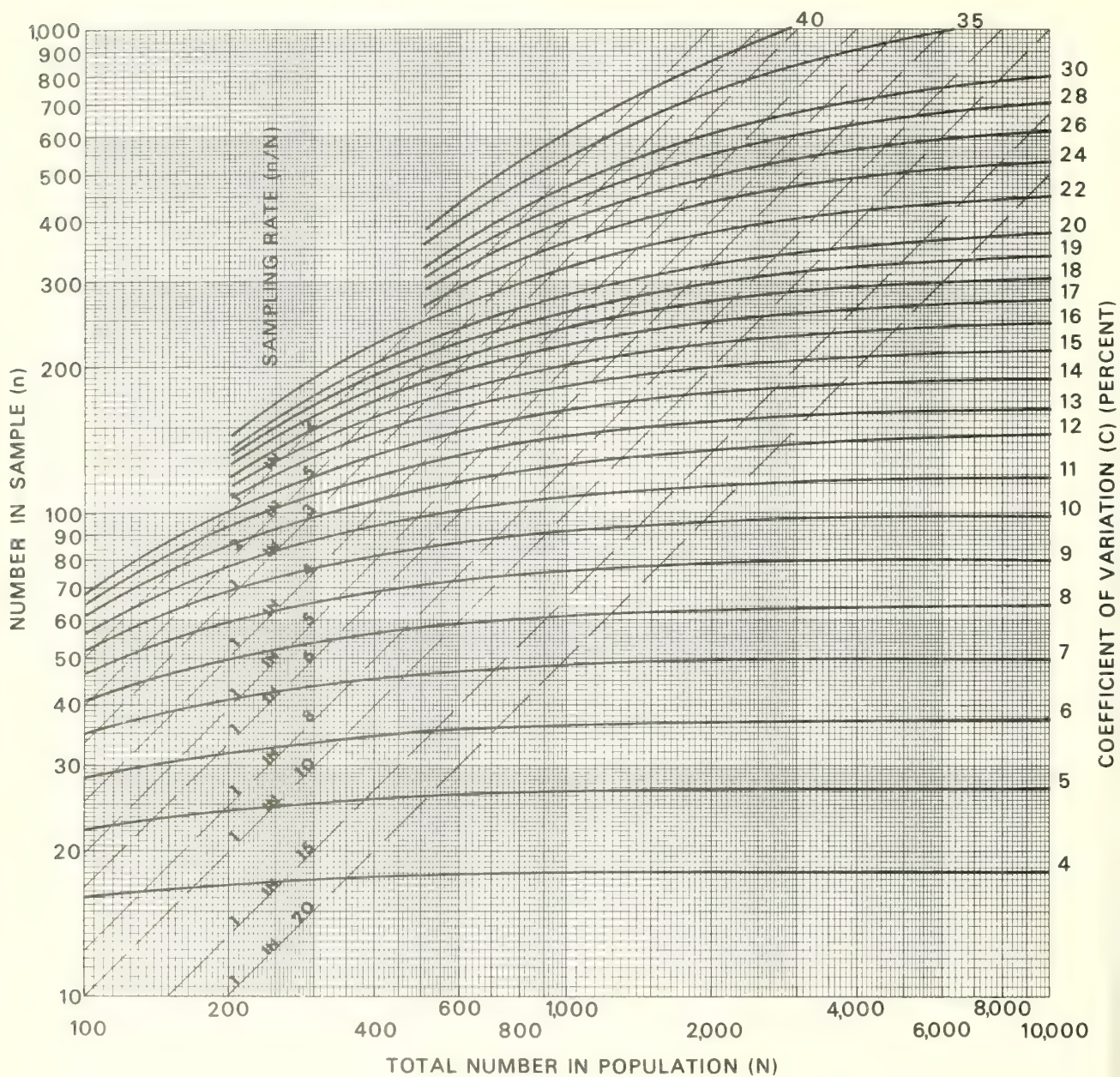
RATE OF SAMPLING

BASED ON DESIRED ACCURACY (E) OF 1-PERCENT AND 95-PERCENT PROBABILITY



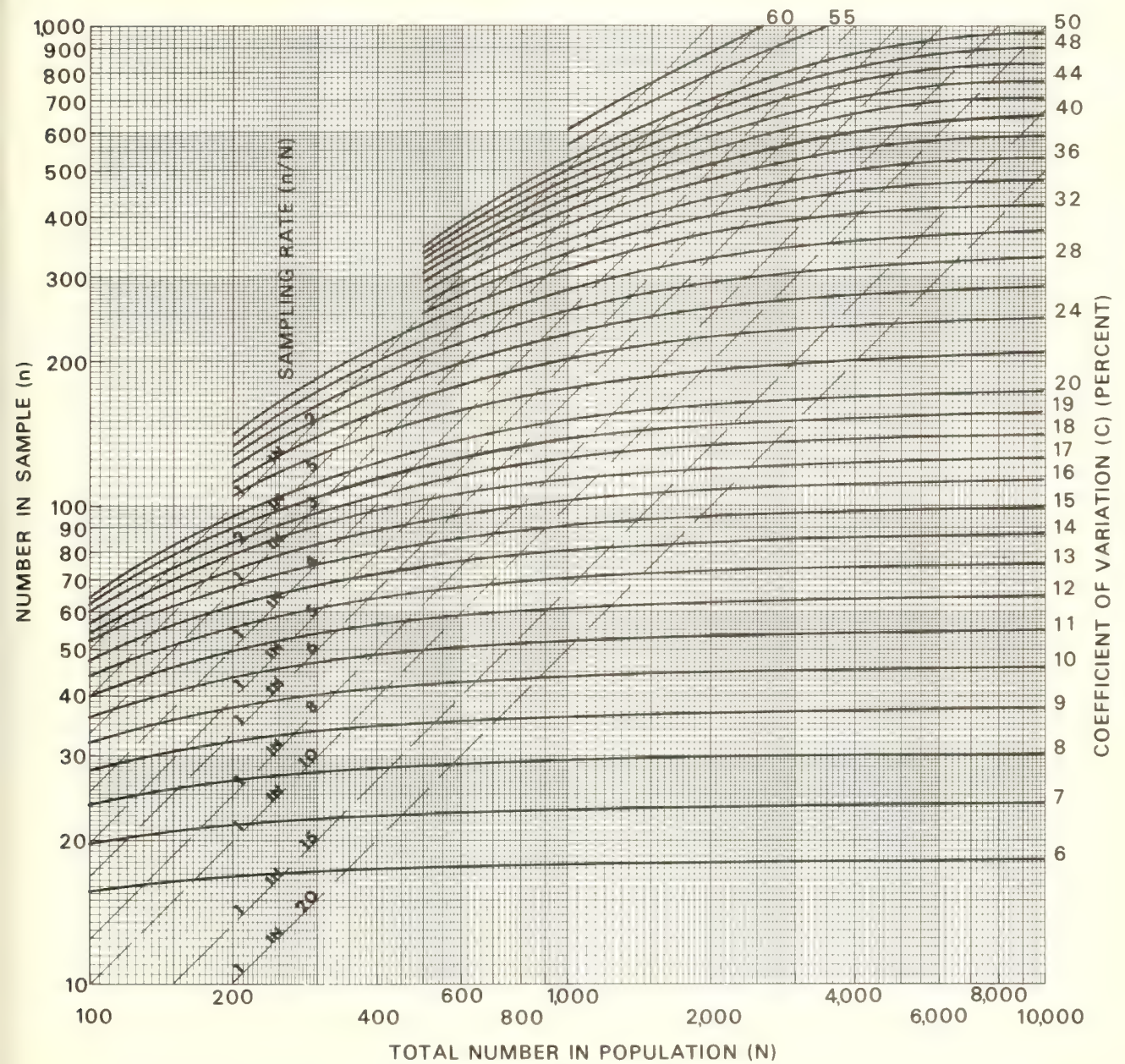
RATE OF SAMPLING

BASED ON DESIRED ACCURACY (E) OF 2-PERCENT AND 95-PERCENT PROBABILITY



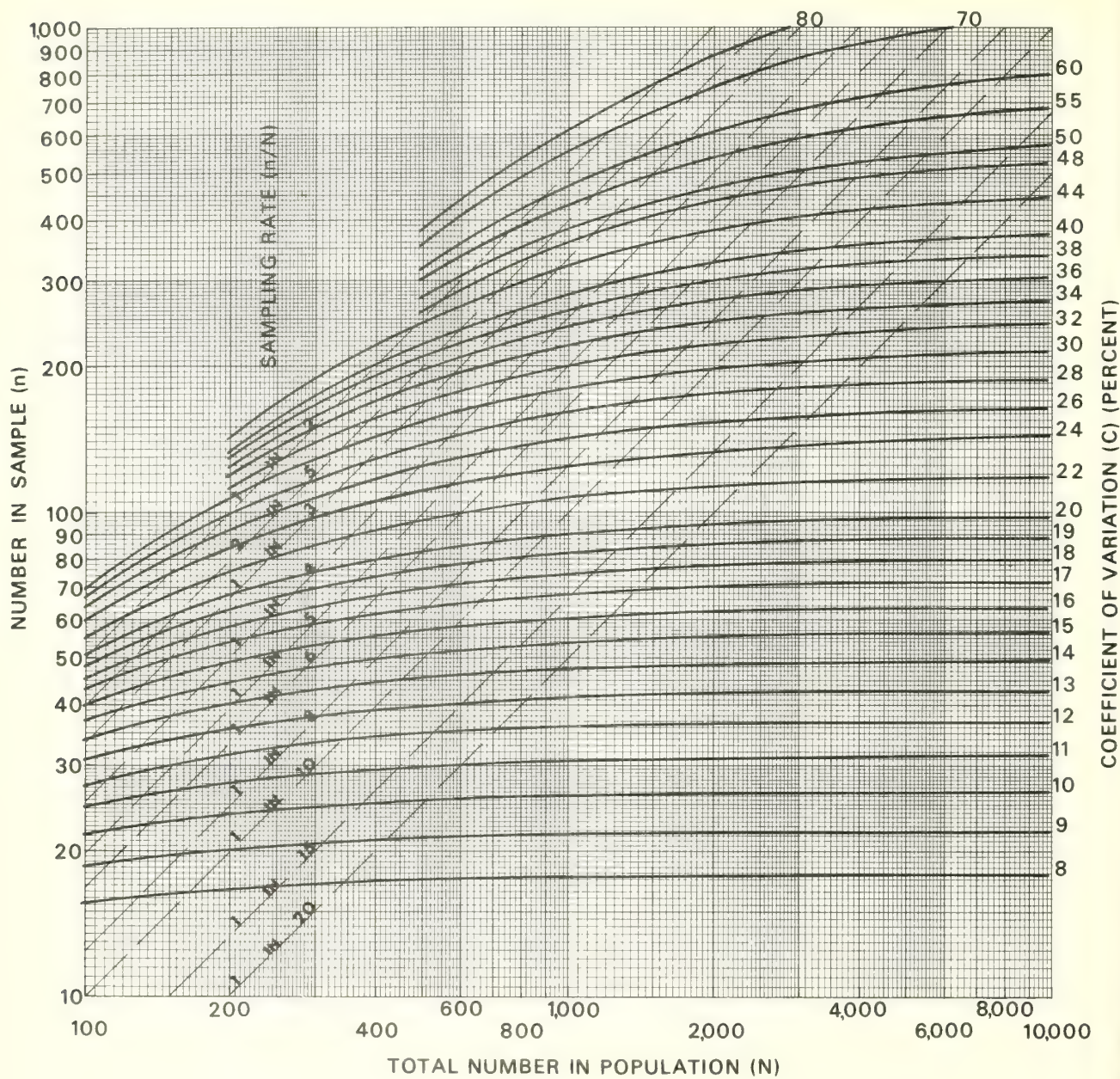
RATE OF SAMPLING

BASED ON DESIRED ACCURACY (E) OF 3-PERCENT AND 95-PERCENT PROBABILITY



RATE OF SAMPLING

BASED ON DESIRED ACCURACY (E) OF 4 -PERCENT AND 95 -PERCENT PROBABILITY



PNW-98

March 1969

A DIGITAL INDICATOR FOR MAXIMUM WINDSPEEDS

by

William B. Fowler, *Meteorologist*



ABSTRACT

A simple device for indicating maximum windspeed during a time interval is described. Use of a unijunction transistor, for voltage sensing, results in a stable comparison circuit and also reduces overall component requirements. Measurement is presented digitally in 1-mile-per-hour increments over the range of 0-51 m.p.h.

Voltage output from a generator-type anemometer can be displayed in a variety of ways. A display suitable for photorecording was required during a recent study. Digital presentation in the camera field (using simple decimal code) was selected for maximum legibility and accuracy over the more obvious analog format. Maximum windspeed during the time interval between film exposures was chosen as the more significant wind parameter to be recorded, although instantaneous windspeed could have been similarly measured.

The system for measuring peak windspeed requires the following:

- (1) Reference voltage generation,
- (2) Voltage comparison,
- (3) One-way rebalancing, and
- (4) Readout and reset.

Reference voltages are produced with a 52-resistor series divider operating at a low current level from a stable mercury battery. The

series divider was chosen to utilize a number of precision resistors and an available 52-position stepper switch. The 51 fixed resistors in the chain were 0.1-percent tolerance. A wire-wound variable resistor completes the chain and allows for proper calibration of all steps in the chain. More inexpensive 5- or 10-percent tolerance components can be used if selected and positioned properly in the chain.^{1/}

The reference source voltage is 6.75 v., which is adequate for a peak windspeed in excess of 51 m.p.h. The final wire-wound resistor in the chain creates the necessary voltage drop from the reference battery to establish the proper voltage steps of about 100 mv. per m.p.h. The drop across the variable resistor is then about equivalent to an 18-m.p.h. step.

Other voltage dividers^{2/} could have been used here with equal success. An example of a parallel divider would be the Kelvin-Varley or one of its variants. These parallel dividers require several stepping switches but reduce the number of rebalancing steps. A parallel divider also offers the possibility of increase in full-scale measurements.

Voltage comparison is performed in a simple circuit incorporating a unijunction transistor (fig. 1).^{3/ 4/} Out-of-balance conditions requiring higher reference voltages fire the unijunction and the silicon-controlled rectifier (SCR) providing stepped voltage increments until balance is obtained. If input voltage from the anemometer equals or is less than the reference voltage, the system is stable. Thus only the maximum voltage is registered. Sensitivity of this voltage comparison circuit is adequate to isolate the approximately 100-mv. steps equaling the 1-m.p.h. increments. A long-term stability of 10 mv. or better is claimed for the comparison circuit which insures a stable calibration. To minimize power supply variation and its effects on circuit operation, the comparison circuit also operates on mercury cells.

^{1/} Owen, R. P. Forming accurate dividers with nonprecise resistors. *Electronics* 38(20): 100-101, illus. 1965.

^{2/} Non-Linear Systems, Inc. Digital voltmeters. 208 pp., illus. Del Mar, California. 1962.

^{3/} Sylvan, T. P. The unijunction transistor characteristics and applications. Application Note 90.10, 95 pp., illus. Syracuse: G.E. Semiconductor Products. 1965.

^{4/} General Electric Co. Transistor Manual, Sixth Edition. 456 pp., illus. Syracuse: G. E. Semiconductor Products. 1962.

Two steps are required to establish the proper threshold for the unijunction transistor comparison circuit. With the input shorted and the reference battery removed, R_0 is adjusted to a point where the circuit is about to fire. Next, R_0 is adjusted such that an input voltage equal to 1 m.p.h. will cause the unijunction to fire and the stepper to advance continuously. Resistor R_t is adjusted for maximum temperature stability. It may be necessary to readjust R_0 after R_t has been adjusted.

Calibration consists of setting the voltage steps along the divider chain equal to the 1-m.p.h. voltage increments produced by the anemometer. This may be done in a wind tunnel where windspeed can be accurately determined. By adjustment of the single series resistor, all steps are established in the proper sequence. At a constant windspeed, the stepper is reset, then allowed to step to the stable position. Adjustment of the divider chain series resistor is continued until readout indicates proper windspeed.

Reset is accomplished at the end of each sample period by actuating the stepper to the home or zero position. At the end of this reset cycle, if the anemometer is producing a voltage, the voltage comparison circuit senses an unbalance and causes the stepper to cycle to the appropriate balancing voltage along the divider chain.

Readout of the peak windspeed is by coded lights. Simple decimal coding on the stepper provides the contact closures for the light bank presentation. The light bank is illuminated slightly prior to the camera pulse and the stepper is reset at the termination of the camera sequence.

The system is battery operated, a requirement for this type of unattended service. Current drain is low; regulation of supplies is not critical with the exception of the reference supply.

Manual test and reset functions can be added for determination of satisfactory operating conditions. Manual reset is accomplished as shown on the schematic diagrams (fig. 1). A test function for simulation of a peak windspeed consisted of a single-pole, double-throw, pushbutton switch to disconnect the anemometer and connect a reference battery to the input terminals.

Parts layout is not critical; the arrangement used (fig. 2) was adequate. An edgewise voltmeter used to monitor input voltage on an instantaneous basis has been removed for clarity. It is not required for normal operation.

Pacific
North
West Forest and Range Experiment Station
A. Forest Service **RESEARCH NOTE**

PNW-99

March 1969

CAN AUGER PLANTING IMPROVE SURVIVAL OF DOUGLAS-FIR SEEDLINGS?

by
Richard E. Miller, *Soil Scientist*

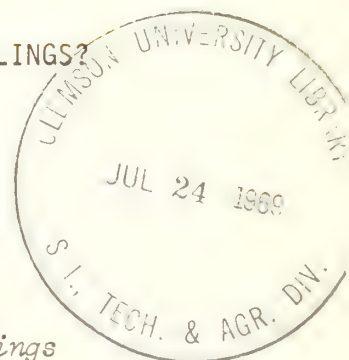
ABSTRACT

Survival and apparent vigor of Douglas-fir seedlings were compared after: (1) hoe planting of root-trimmed seedlings; (2) as above, plus manual site preparation; and (3) auger planting of untrimmed seedlings. After two growing seasons, survival with method (3) but not (2) was significantly greater than survival with method (1). After the third season, survival differences were no longer statistically significant. Survival percentages were 40, 52, and 60 for methods (1), (2), and (3), respectively; and 50, 85, and 67 percent of the survivors were judged healthy. These results are discussed in relation to survival and cost data from other trials of auger versus hoe planting.

INTRODUCTION

Planting root-pruned seedlings with a hoe is the most common planting method used in the Pacific Northwest, but there is increasing interest in planting seedlings in holes dug by power auger. This interest has been intensified by demands for higher survival and more rapid growth of planted stock, improvement of lightweight power augers, and some regional evidence that auger planting may reduce the cost per surviving seedling.^{1/}

^{1/} Dahl, Harold. Mechanical augers for tree planting on adverse sites. British Columbia Reforest. Board, Tree Farm Forest. Comm. 1966, Reforest. Work Proc. 6 pp. 1966.



A small-scale trial was initiated on an extensively distributed forest soil in southwestern Oregon to measure possible benefits from auger planting over regular or modified hoe planting of Douglas-fir on adverse sites. First-, second-, and third-year survival and apparent vigor are reported and discussed in relation to other trials comparing hoe and auger planting of Douglas-fir in western Washington and Oregon.

MATERIALS AND METHODS

Study Area

The study was located on a recent clearcut in the Cascade Range of southwestern Oregon. This clearcut--near Steelhead Creek, Steamboat Ranger District, Umpqua National Forest--was logged in the summer and burned and planted in the fall of 1963, 2 years before the study began. The study was conducted within a 1-acre, deer- and rabbit-proof exclosure at an elevation of 2,500 feet on a southeasterly, 20-percent slope. The soil (probably Dumont loam) was a dark, reddish-brown, well-aggregated, "shotty" loam developing on red-colored tuff with slight admixture of basalt colluvium.

Methods

Each of three groups of 25 seedlings was planted according to one of the following methods:

- (1) Normal or hoe planting of root-trimmed seedlings.
- (2) As above, plus removal of the upper 6 inches of soil in a 2-foot radius around the final seedling location prior to planting.
- (3) Auger planting of untrimmed seedlings.

Thus, normal planting (1) was compared with two alternatives aimed at increasing seedling access to available soil moisture. Scraping aside the "shotty," upper soil layer in (2) permitted planting the pruned root system in a deeper, finer textured soil horizon and delayed reestablishment of competing vegetation. Auger planting of seedlings with untrimmed roots in (3) placed a longer, intact root system deeper into the soil.

Study Installation

In early December 1965, approximately 100 seedlings (2-1) of a local seed source were lifted from a nearby transplant bed. On the following day, 75 of these seedlings of comparable size and vigor were divided into three groups; each group was randomly assigned a treatment.

Two of the three groups were root-trimmed to reduce roots from 13 inches ($\pm$ 3) to 8 inches in length. Each group was then packed with moist sphagnum moss in a plastic bucket.

One seedling for each method was planted at each of 25 locations within the enclosure. At each location, the three methods were randomized and the seedlings were planted 4 to 5 feet apart under comparable conditions in regard to stumps, logs, soil disturbance, and apparent intensity of past slash burning. All vegetation taller than 6 inches and within 3 feet of a seedling was grubbed out with a planting hoe. All planting was done by one person, one method at a time. For method (3), the last group planted, a 4-inch-diameter hole approximately 18 inches deep was bored with a power auger.

Data Collection and Analysis

Seedling survival and apparent vigor were recorded at monthly intervals throughout the first growing season (1966). Additional observations were made at the beginning (May) and end (November) of the second and third growing seasons. Number of all survivors and of healthy survivors (those seedlings whose needles were nonchlorotic and at least three-fourths inch long) were analyzed statistically.

RESULTS

Survival and Vigor

Survival percentage throughout the 3 years was greatest with auger-planted untrimmed stock (3), and somewhat less with hoe-planted root-trimmed seedlings and site preparation (2) (table 1). Survival percentage was consistently lowest with hoe-planted root-trimmed seedlings (1). Of the 25 seedlings planted by each procedure, 84 percent survived the first growing season in (3) and (2), compared to 56 percent in (1). This difference was statistically significant. Losses during the following winter and second growing season reduced survival percentages to 76, 52, and 40 in (3), (2), and (1), respectively; survival in (3) remained significantly greater than (1) and became significantly greater than (2). Survival of (2) was no longer significantly different from that of normal hoe planting without site preparation. After three growing seasons, differences in seedling survival remained but were no longer statistically significant. Survival percentages were 60, 52, and 40 in treatment (3), (2), and (1), respectively.

The number and proportion of healthy seedlings--those of normal stature and with needles of normal length and nonchlorotic color--increased with successive growing seasons and were consistently greater in (3) and (2) than in (1) (table 1). At the end of three growing seasons, the

proportion of healthy trees was 67, 85, and 50 percent, respectively. Although the differences are not statistically significant, they do indicate greater potential for survival in (2) and (3) seedlings.

Table 1.--*Number of surviving and of healthy 2-1 Douglas-fir seedlings planted by three different methods*^{1/}

Methods	First growing season		Second growing season		Third growing season	
	Alive	Healthy ^{2/}	Alive	Healthy ^{2/}	Alive	Healthy ^{2/}
(1) Root-pruned, hoe-planted	14	0	11	1	10	5
(2) Root-pruned, hoe-planted, with surface soil removed	21	4	13	6	13	11
(3) Unpruned, auger-planted	21	5	19	9	15	10
Total	56	9	43	16	38	26

Note: Means connected by a vertical line are not significantly different at the 5-percent level.

^{1/} 25 seedlings per method.

^{2/} Seedlings had normal stature and needles that were nonchlorotic and at least 3/4 inch long.

Timing and Probable Causes of Seedling Mortality

Most mortality in the normal, hoe-planted seedlings occurred during the first growing season. In (2) and (3), however, most mortality was delayed to the second and third growing seasons, respectively (table 2).

Causes of seedling mortality may be surmised. Lack of root regeneration, resulting in reduced moisture and nutrient uptake, was a probable cause of mortality. Root regeneration (postplanting root growth) was evaluated by

examining the excavated root systems of dead seedlings. Of the 37 seedlings which died by the end of the third growing season, only six evidenced any root regeneration (table 2).

Table 2.--*Number of dead seedlings by planting method^{1/} and after indicated growing season*

Method	First growing season	Second growing season	Third growing season	Total
(1) Root-pruned, hoe-planted	11 (1) ^{2/}	3 (0)	1 (1)	15 (2)
(2) Root-pruned, hoe-planted, with surface soil removed	4 (0)	8 (1)	0 (0)	12 (1)
(3) Unpruned, auger-planted	4 (0)	2 (1)	4 (2)	10 (3)
Total	19 (1)	13 (2)	5 (3)	37 (6)

^{1/} 25 seedlings per method.

^{2/} Figures in parentheses indicate number of dead seedlings showing postplanting root growth.

Snow and frost damage may have contributed to seedling mortality, but the evidence is not strong. Wet snowfall during the first winter depressed two-thirds of all seedlings and most retained a bowed stature through the first growing season. Damaging frost occurred in June and September of the first growing season. Damage from frost and/or snow was about equal in all methods, and the proportion of seedlings which subsequently recovered or died was similar.

DISCUSSION AND CONCLUSIONS

Where can auger planting improve survival of Douglas-fir seedlings? Planting method and stock should be fitted to meet anticipated regeneration problems at each site. On relatively favorable sites, such as in coastal areas of western Washington and Oregon and on northerly aspects in the Cascade Range, hoe planting 2-0 Douglas-fir seedlings may commonly

provide regeneration at a low cost per established tree. On unfavorable sites, however, successful regeneration requires additional effort such as closer supervision of crews, site preparation, auger or container planting, use of older seedlings, control of competing vegetation, and protection from animals. It is the forester's responsibility to determine where and what extra effort and cost are necessary to achieve satisfactory stocking and cost per established tree.

The present test was conducted on a productive but difficult-to-regenerate site in southwestern Oregon. The results of this small, relatively sensitive field experiment can be judged by examination of trends of survival and by use of the proportion of healthy seedlings as an index of survival potential. By the end of the third growing season, survival percentages were 40, 52, and 60 for methods (1), (2), and (3), respectively. Although these differences among methods were no longer statistically significant, the greater proportion of surviving and of healthy seedlings in (2) and (3) after each growing season are bases for recommending further testing of site preparation or auger planting as alternatives to regular hoe planting on similar, adverse sites.

Two previous studies conducted within this exclosure had demonstrated regeneration problems with either hoe planting or seed spotting. For example, in one trial conducted by Umpqua National Forest personnel, only 28 percent of planted 2-0 Douglas-fir survived the first growing season.^{2/} This is considerably less survival than that attained with hoe planting 2-1 stock in this present study. In the second study, 8 percent of the seedlings which germinated in prepared seed spots survived the first growing season (compared to 10, 36, and 38 percent at three other exclosures in the Umpqua River drainage).^{3/} Poor germination and survival at Steelhead Creek were associated with earlier (1 month) and higher (163°F. versus 150°F.) maximum soil surface temperatures (determined with "Tempils," commercial temperature pellets) than at the other three exclosures. There was also more rapid and complete drying of the upper 4 inches of soil.

The present study was not designed to measure gains in survival from auger planting of seedlings with smaller root systems, because an additional method (auger planting root-trimmed stock) was not tested. Thus, increased survival and vigor in (3) could be due to untrimmed roots, method of planting, or both. There is some basis for expecting

^{2/} Personal communication with Ray Zalundardo, September 1966.

^{3/} Data on file at Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Olympia, Washington.

comparable results with root-trimmed stock. Huntly^{4/} concluded that root pruning (trimming) as much as one-half the shoot height did not reduce survival of Douglas-fir seedlings transplanted in the nursery. Moreover, results of a field trial discussed later in this paper suggest that root trimming 2-2 transplants--a common nursery practice--did not reduce survival at an adverse site in south-central Washington when planting was carefully done. If further testing supports this interpretation, then auger planting could be more cheaply and probably better done on an operational basis by use of stock which is root trimmed at the nursery.

The results of the present study can be related to survival and cost data from other trials to help determine where auger planting might reduce the cost per surviving seedling of Douglas-fir. On adverse sites in the Bear Springs Ranger District of the Mount Hood National Forest, auger planting of root-trimmed stock has apparently provided better survival than has hoe planting.^{5/} For example, on five clear-cut units, first-year survival after hoe planting ranged from 1 to 9 percent. Replanting these same units by auger resulted in 35- to 55-percent survival. Contract planting costs per surviving tree were approximately \$0.65 for hoe planting and \$0.18 for auger planting. Obviously these comparisons are confounded by numerous factors since augers and hoes were not used in the same years. Despite these shortcomings, however, the consistent results of these and other local trials support this District's preference for auger planting on adverse sites with gentle to moderate slopes and nongravelly soils. Even though contract costs are about 50 percent greater for auger planting, use of this method on adverse sites of this District would probably result in a manyfold increase in survival of Douglas-fir seedlings.

At locations farther north, other comparisons of planting Douglas-fir have not demonstrated increased survival from auger planting. On the Glenwood District in south-central Washington, the Department of Natural Resources planted 2-2 Douglas-fir in a 4-year-old clearcut located on a 30-percent slope of southeast exposure. In past District experience, this was a difficult site to regenerate. Survival

^{4/} Huntly, J. H. Assessment of survival and growth prospects of seedlings of Douglas-fir, *Pseudotsuga menziesii*. 55 pp. 1960. (Unpublished M.F. thesis on file at Faculty of Forestry, Univ. British Columbia, Vancouver, B.C., Canada.)

^{5/} Personal communication with Paul F. Schuller, November 13, 1968.

percentages based on 200 seedlings per method (four rows of 50 seedlings each) are as follows:^{6/}

<u>Method</u>	<u>Percent survival</u>	
	<u>First year</u>	<u>Third year</u>
Hoe, roots trimmed	82	70
Auger, roots untrimmed	75	66

Compared to survival of stock planted on an operational basis in the same general area, survival of hoe-planted stock in this study was good. Most likely, these results are attributable to close supervision and good workmanship.^{7/} Although greater survival percent was anticipated for auger planting, no additional gain was achieved from auger planting this larger stock.

A pilot project by Weyerhaeuser Company on a scarified site I north slope in southwestern Washington demonstrated little increase in survival with auger planting.^{8/} Following mechanical scarification, 2-0 Douglas-fir were planted by hoe or power auger; the corresponding number of seedlings planted were 25,000 and 18,000. Second-year survival of a staked 10-percent sample was 89 and 91 percent, respectively, for hoe and auger planting. This 2-percent improvement in percentage of survival with auger planting is not likely to offset the costs of auger planting which were approximately 20 percent greater.

In summary, current regional experience concerning the benefits of planting Douglas-fir with auger is limited and does not support general application of this tool. Practical gains from auger planting are most likely on sites where soil moisture is deficient, but where topography and soils are favorable for auger operations. Suggesting that auger planting generally provides a greater allowance for error, some investigators urge use of mechanical augers instead of planting hoes by inexperienced or inadequately motivated planting crews.^{9/} Additional testing is necessary before we can determine and subsequently predict specific planting conditions under which the additional expense of auger planting Douglas-fir is justified.

^{6/} Personal communication with J. M. Finnis, November 1968.

^{7/} Ibid.

^{8/} Personal communication with William Schmidt, November 15, 1968.

^{9/} Personal communication with J. M. Finnis, November 1968, and Paul F. Schuller, November 13, 1968.

Pacific
North
West Forest and Range Experiment Station
Forest Service **RESEARCH NOTE**

PNW-100

April 1969

CROP-TREE THINNING OF PONDEROSA PINE
IN THE PACIFIC NORTHWEST

by

James W. Barrett
Silviculturist



ABSTRACT

Three Pacific Northwest thinning studies showed that diameter growth of young ponderosa pine was substantially increased by cutting all trees within 5 to 8 feet of the crop tree. An additional increase in diameter growth was obtained by overstory removal. Thinning did not increase height growth of young crop trees, but overstory removal did.

During the 1930's in some parts of the United States, thinning ponderosa pine (*Pinus ponderosa*) changed from area to the crop-tree method.^{1/} This was largely an economy move simply because the crop-tree method did not require hand cutting by axe of as many trees as did area thinning. In more recent years, the advent of the lightweight powersaw has given preference to area thinning, although some crop-tree thinning is still being done in conjunction with pruning.

This paper presents results of three crop-tree thinning experiments established at a time when the crop-tree method seemed advisable for economic reasons.

^{1/} In this note, crop-tree thinning is the cutting of all trees within a designated distance of a tree to be left as contrasted to area thinning where all trees are cut except selected leave trees.

Mowat^{2/} has reported on several earlier crop-tree thinning studies made in the Pacific Northwest. Thinning treatments varied from removing only trees with interlacing crowns to cutting all trees whose crowns were within 3 feet of the crop tree. Differences between growth of released and unreleased trees were small. Heavily released trees grew at the rate of only about 1 inch per decade compared to 0.7 inch for selected crop trees in the unthinned stand. Furthermore, these early experiments did not show any clear-cut effect of overstory on understory tree growth and vice versa.

The studies reported here go a step further as some crop trees were released to a point that approached area thinning. In addition, the interrelationships of overstory and understory tree growth were examined. Results are important to land managers who have trees already released by the crop-tree method and to managers who intend to embark on an extensive thinning program in ponderosa pine.

THE THREE STUDIES

Chelan Study

This experiment was located 15 miles south of Twisp, Washington, on the edge of the 1929 Camas burn on a high IV site.^{3/} Reproduction, composed mostly of ponderosa pine but with a sprinkling of Douglas-fir, was established from a natural seed source after fire. The young trees grew rapidly for 10 years, but competition soon reduced individual tree growth to very slow rates. When the study was initiated in 1953, the sapling and small pole stand was 23 years old and contained about 2,500 trees per acre. A few overstory trees were present around the perimeter of the plot.

The study plot, 3 by 5 chains, was subdivided into four subplots 1.5 by 2.5 chains. From the total of 140 ponderosa pine crop trees selected on the plot, 25 trees were randomly chosen on each subplot as study trees. Two of the subplots were randomly selected for crop-tree release and two left unthinned.

Treatment consisted of cutting all stems within 8 feet of the crop tree's bole. This procedure sometimes resulted in overlapping of cut circles and sometimes in separation of cut circles by islands and strips of uncut trees.

^{2/} Mowat, E. L. Thinning ponderosa pine in the Pacific Northwest. U.S.D.A. Forest Serv. Pacific Northwest Forest & Range Exp. Sta. Res. Pap. 5, 24 pp., illus. 1953.

^{3/} Meyer, Walter H. Yield of even-aged stands of ponderosa pine. U.S. Dep. Agr. Tech. Bull. 630 (rev.), 59 pp., illus. 1961.

Height and diameter were measured on all crop trees in 1953 and five growing seasons later in 1958. In addition, a count by 1-inch diameter classes was made of all living trees within an 18.6-foot radius (one-fortieth acre) around each tagged crop tree.

Snoqualmie Study

This experiment was located in a stand consisting of scattered old-growth ponderosa pine overstory trees with a dense even-aged understory. Site was IV.^{4/} Existing stand basal area at the time of study establishment averaged 130 square feet per acre of which 40 square feet was overstory. Understory trees averaged about 1,500 per acre.

Two plots approximately 10 acres each were established in 1951 on the south fork of the Tieton River about 50 miles west of Yakima. Fifty study trees in each plot were randomly selected from previously marked crop trees. On one plot, all trees within 7 feet of the crop trees were cut. Crop trees on the other plot were not released.

Study trees were tagged 4.5 feet from the ground and height and diameter measured in 1951, 1956, and 1961. Also, a count by 1-inch diameter classes was made of all living trees within an 18.6-foot radius around each tagged crop tree. Tree vigor was recorded for each crop tree. In dense thickets, crop-tree spacing was close enough so that cut circles overlapped; but where stocking was sparse, competition between trees low, and good crop trees difficult to find, spacing was wide.

Metolius Study

This was the most extensive ponderosa pine crop-tree thinning study made in the Northwestern United States. It was located about 20 miles north of Sisters, Oregon, in the Abbot Butte area at an elevation of 3,200 feet. Topography varied from flat to gentle southwesterly slopes. Overstory trees indicated an average site IV.^{5/} Although no local records are available, local precipitation was estimated at 25 inches per year.

The stand before treatment consisted of overmature trees averaging 13,400 board feet per acre. Overstory mortality from bark beetles has been fairly heavy as evidenced by numerous snags. At the time of study establishment, overwood was considered light compared to other mature stands on the Deschutes National Forest. No light ground fires

^{4/} See footnote 3.

^{5/} See footnote 3.

have occurred for about 40 years, and a fairly dense understory of ponderosa pine saplings and poles 10 to 25 feet high and 1 to 5 inches in diameter developed. The understory, originating after a heavy fire, was even aged at 63 years in 1951, when the study was established. Before treatment, there was considerable variation in tree density and thus tree size. Numbers of understory trees ranged from 1,590 to 5,460 per acre and averaged 3,200.

Original objectives of the study were to determine

- (1) optimum thinning distance around each crop tree,
- (2) most desirable crop-tree spacing,
- (3) effect of overstory on growth of released and unreleased trees, and
- (4) effect of understory on overstory growth.

The experiment was established on four 20-acre plots. On two randomly selected plots all merchantable overstory was removed. On the remaining two plots, a light selection cut in the overstory was made which removed about 22 percent of the existing volume, leaving about 10,500 board feet per acre standing. In each 20-acre plot, treatments were assigned at random to five 4-acre subplots.

The five treatments assigned to subplots consisted of crop-tree selection with the following specification:

<u>Average crop-tree spacing</u>	<u>Circle of release diameter</u>	<u>Theoretical area thinned</u>
(Feet)	(Feet)	(Percent)
15	0	0
30	<u>1/</u> 10	9
30	<u>2/</u> 15	20
15	10	35
15	15	79

1/ See figure 1.

2/ See figure 2.

Forty crop trees in each 4-acre subplot were randomly selected for growth measurements. Trees were tagged and diameter measured at breast height to the nearest 0.1 inch and height measured to the nearest 0.1 foot with a jointed aluminum pole. Measurements were taken in 1951, 1956, and 1961, giving a 10-year record of growth.



Figure 1.--All trees within 5.0 feet of this crop tree were cut.



Figure 2.--All trees within 7.5 feet of this crop tree were cut. Ribbons designate the boundaries of the release circle.

As an index of existing and past competition, standing and cut trees within an 18.6-foot (1/40-acre) circle of the crop tree were measured in diameter and basal area computed. As an index of overwood competition, all trees 8 inches d.b.h. and larger within a 1/4-acre circle of each of 80 randomly selected crop trees were measured in diameter and basal areas were computed. For evaluation of the effect of thinning on reserve overwood trees on partial-cut plots, 10 over-story trees were chosen and tagged in areas of the subplots representing fairly heavy understory tree competition and little effect from cutting other large trees. Increment cores were extracted from over-story trees to determine growth differences before and after thinning.

RESULTS

Diameter Growth

Released trees grew more in diameter than unreleased trees in all three studies (table 1). Diameter growth was increased to the rate of nearly 2 inches per decade by crop-tree thinning. In all cases, larger trees grew faster than smaller trees (fig. 3). Tree vigor, which included crown length and density and needle length and color, was a better indicator of crop-tree growth potential than tree size (figs. 4 and 5). High vigor trees responded better to release than low vigor trees; however, it was apparent in the Metolius study that low vigor trees do maintain the capacity to respond, indicating the validity of the common practice of leaving a low vigor tree where necessary to stock an area.

Table 1.--Average diameter growth of released and unreleased crop trees on each study

Study	Released crop trees		Unreleased crop trees	
	First 5 years	Second 5 years	First 5 years	Second 5 years
----- Inches -----				
Chelan	1.06** ^{1/}	--	0.62	--
Snoqualmie	.95**	0.80**	.53	0.45
Metolius	.82*	.92*	.59	.72

^{1/} Test of significance between comparable means of released and unreleased stands:

level. ** Significant at 1-percent level.
level. * Significant at 5-percent level.

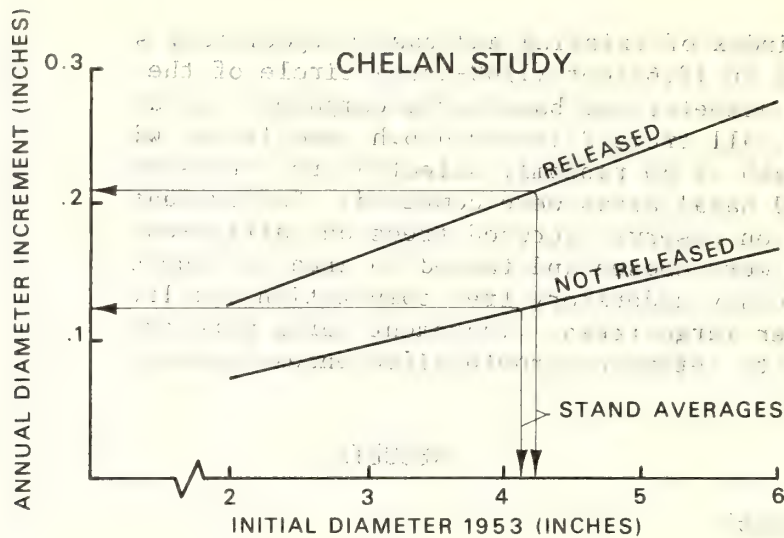


Figure 3.--Average annual diameter increment in relation to initial diameter.

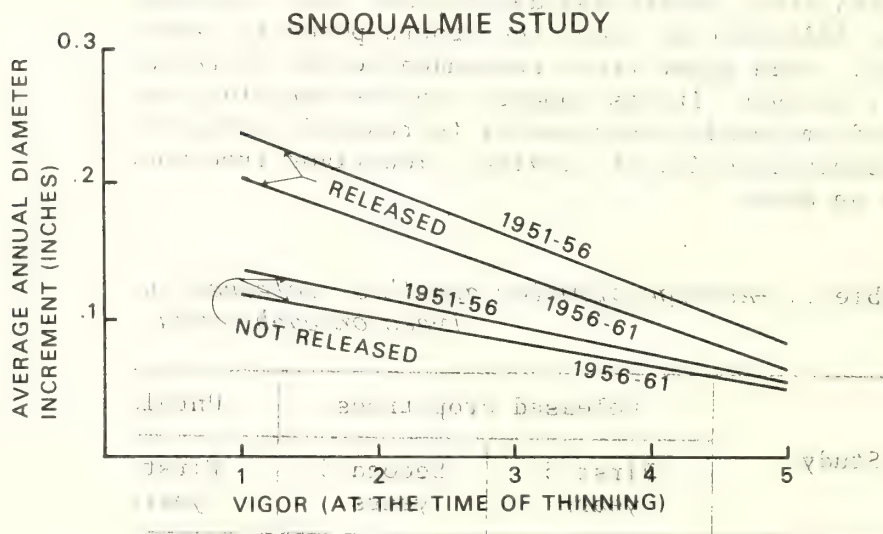


Figure 4.--Relationship of annual diameter increment of released and unrelased trees to crop tree vigor. Trees were rated for vigor on a scale from 1 to 5. Number 1 vigor class is a tree of high vigor having more than 55 percent of its height in crown contrasted to number 5, the lowest vigor class, having from 10 to 30 percent of its total height in crown, with short, thinly distributed needles.

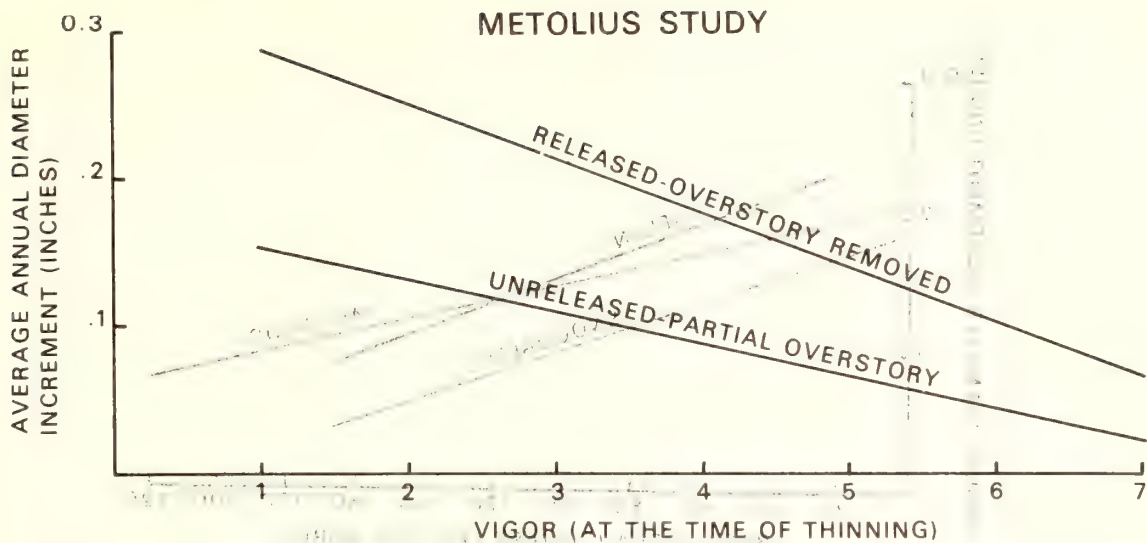


Figure 5.--Relationship of annual diameter increment to tree vigor with treatment. Trees rated for vigor on a scale from 1 to 7. Number 1 vigor class denotes a tree of high vigor having more than 55 percent of its height in crown contrasted to number 7, the lowest vigor class, having less than 10 percent of the total height in crown, and with short, thinly distributed needles.

Diameter growth was inversely correlated with basal area of competing trees within the 18.6-foot circle around the crop tree (fig. 6). For example, in the Chelan study, trees that grew 1 inch per decade had competition surrounding them at the rate of about 160 square feet per acre compared to only 50 square feet where trees were growing 2 inches per decade.

In the Metolius study, the 15-foot circle of release with 15-foot spacing where overstory was partially removed (fig. 7) provided significantly better growth to crop trees than the other three degrees of release and spacing. No thinning treatment was significantly outstanding where the overstory was completely removed. The treatment of 10-foot release with 30-foot spacing and complete overstory removal appears outstanding (fig. 7). However, on-the-ground examination of this treatment revealed that growth can be related to a large amount of logging damage to understory trees surrounding released crop trees.

Removal of merchantable overstory improved diameter growth of crop trees in the Metolius study (fig. 7). Trees on plots where the overstory was removed grew 2.1 inches per decade compared to 1.3 inches where part of the overstory was left (significant at the 1-percent level). Unreleased trees were affected as well as released trees. Crop-tree diameter growth in the unreleased stand was reduced an average of about 46 percent by the presence of an overstory.

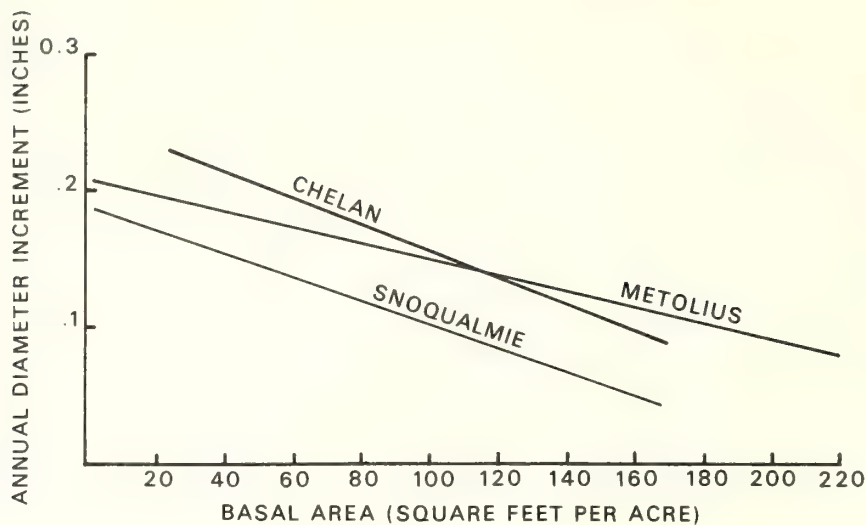


Figure 6.--Relation of average annual diameter increment to the basal area of living tree competition within an 18.6-foot radius around each crop tree (one-fortieth acre). (Released and unreleased trees combined in each experiment).

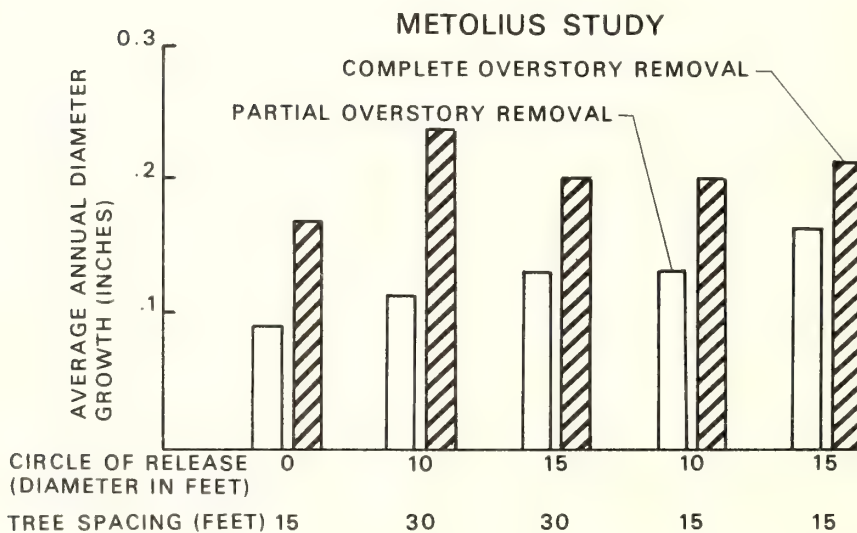


Figure 7.--Average annual diameter growth of saplings and small poles during the 10 years after release.

Attempts to derive a prediction equation for diameter growth by use of multiple regression techniques were not successful. Using the independent variables initial diameter, vigor, cut basal area, overstory basal area and basal area of the young stand in a 1/40-acre circle around the crop tree, the author was able to account for only 56 percent of the variation in diameter growth. Vigor was always the strongest predictor variable; however, it was strongly intercorrelated with some of the other variables.

Height Growth

Thinning did not affect height growth. Crop trees on the Chelan study grew almost a foot per year and those on the Snoqualmie study averaged about 0.7 foot per year.

The Metolius study showed a trend (approaching significance at the 5-percent level) for overstory trees to reduce height growth of crop trees during the second period of observation (fig. 8). Annual height growth averaged 0.66 foot where overstory was completely removed and 0.59 where there was a partial overstory.

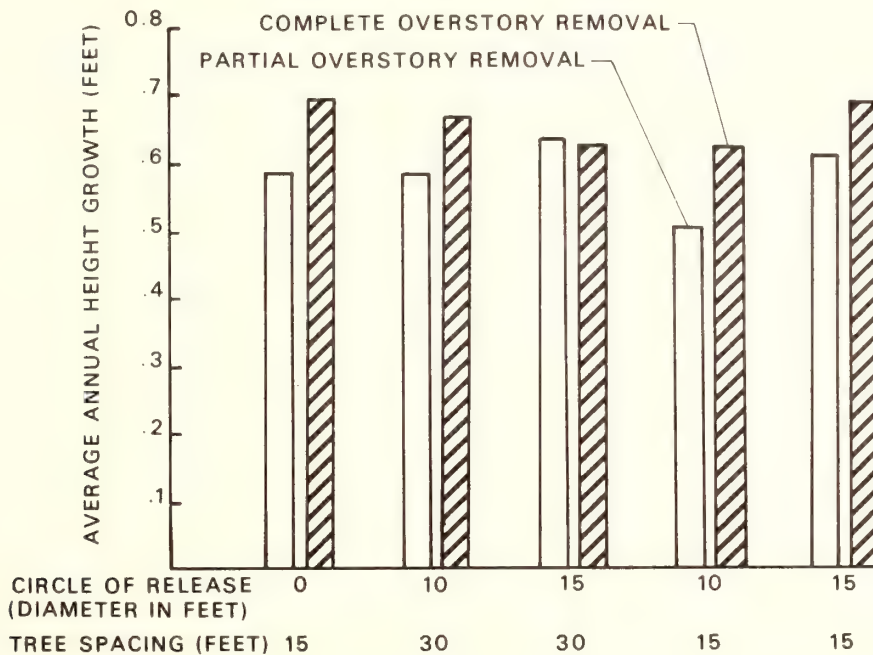


Figure 8.--Average annual height growth of saplings and small poles during the second 5-year period after release.

Attempts to predict crop-tree height growth under varying stand conditions were made with some success. For example, when the variables initial height, previous 5-year height growth, basal area cut around the crop tree, overstory basal area, and basal area of the young stand were used, 68 percent of the total variation in height growth could be accounted for. Past height increment and vigor appeared to be the most important variables.

Overstory Tree Growth

There is good evidence to indicate that understory saplings and poles are competing with overstory trees for soil moisture and nutrients. For example, overstory trees grew better in diameter after understory thinning than before. Furthermore, the greater the amount of basal area removed, the more overstory trees responded to reduced competition (fig. 9). Where 60 percent of the basal area of the understory stand was removed (15-foot spacing and 15-foot circle of release), overstory trees grew 1.4 times better after thinning than 5 years before thinning. Before thinning, overstory trees were growing at an average diameter rate of about 0.9 inch per decade, but cutting 60 percent of the understory increased this rate to about 1.3 inches per decade.

CONCLUSIONS

The most useful conclusion that can be drawn from these studies is that ponderosa pine overstory can retard understory tree growth. And conversely, an understory of saplings can hold back diameter growth of overstory trees.

These studies also show that acceleration of diameter growth can be accomplished by the crop-tree thinning method. In all three studies, diameter growth rates averaged about 2 inches per decade where crop trees were released and overstory was not present. Similar growth rates have been reported for area thinning studies^{6/ 7/} where stands were thinned to about 13 feet. Growth rates above 2 inches per decade were reported in stands where 18- and 26-foot spacings were used and where competing vegetation was removed.

^{6/} Barrett, James W. Response of ponderosa pine pole stands to thinning. Pacific Northwest Forest and Range Exp. Sta. U.S.D.A. Forest Serv. Res. Note PNW-77, 11 pp., illus. 1968.

^{7/} Barrett, James W. Spacing and understory vegetation affect growth of ponderosa pine saplings. Pacific Northwest Forest and Range Exp. Sta. U.S.D.A. Forest Serv. Res. Note PNW-27, 8 pp., illus. 1965.

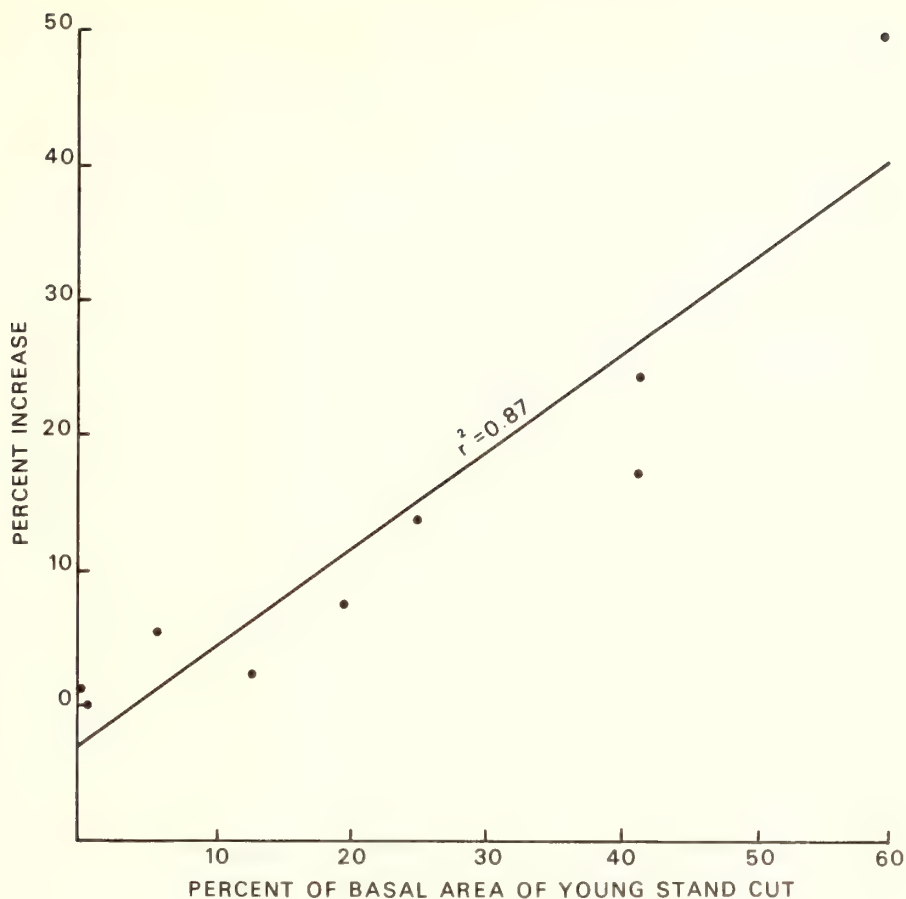


Figure 9.--Percent increase in diameter growth of overstory trees by cutting varying amounts of the understory. Each dot represents average growth of 10 trees.

One is tempted to speculate on the length of time that will elapse before the area in the circle of release in crop-tree thinning will be occupied by roots of the released tree, roots of trees surrounding the circle, and crowns of both, and when diameter growth of crop trees will slow to less desirable rates. This or past experiments will not tell us, but a useful conclusion might be drawn by mentally comparing the 15-foot circle of release and 15-foot spacing to 15-foot spacing with area thinning. One could surely expect the crop-tree thinned trees to slow down first simply because there is more competition from uncut trees between circles.

This and other recent ponderosa pine thinning studies^{8/ 9/ 10/} in the Pacific Northwest indicate that in areas of limited rainfall all living trees in a densely stocked stand are in competition for soil moisture and nutrients. Therefore, ideally, these two important constituents for growth should be allocated only to (a) trees that are capable of adding reasonable increments of usable wood, (b) usable forage, and (c) trees desired for esthetic purposes.

^{8/} Barrett, James W., and Youngberg, C. T. Effect of tree spacing und understory vegetation on water use in a pumice soil. Soil Sci. Soc. Amer. Proc. 29: 472-475, illus. 1965.

^{9/} See footnote 6.

^{10/} See footnote 7.

PNW-101

March 1969

COOLING A DOUGLAS-FIR SEED ORCHARD TO
AVOID POLLEN CONTAMINATION

by

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and

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ABSTRACT

A very cold water spray was used in a Douglas-fir seed orchard to reduce pollen contamination by arresting floral buds in their scales during period of local pollen release. Numbers of pollen grains per cone were thereby reduced from over 1,300 on control plots to a tolerable 100 or less on sprayed plots.

INTRODUCTION

Contamination from outside pollen sources is a major obstacle to developing a successful seed orchard technology for Douglas-fir. Pollen flight in the Douglas-fir region is extensive,^{2/} and during good crop

^{1/} Oakridge Ranger District, Willamette National Forest, Oakridge, Oregon.

^{2/} Silen, Roy R. Pollen dispersal consideration for Douglas-fir. J. Forest. 60: 790-795, illus. 1962.

years, pollen counts are high over all the region. For example, sampling of four nonflowering seed orchards during 1966 in Oregon and Washington showed counts averaging from 2,864 to 6,941 pollen grains deposited per square inch.^{3/} Such high densities of unwanted pollen greatly dilute pollination between seed orchard trees and reduce the genetic value of seed orchard seed.

Among unsuccessful methods explored prior to 1968 for reducing Douglas-fir pollen contamination were pollen-free buffer zones, moving seed orchards to other regions, exploiting expected phenological differences from bringing high elevation selections to low elevation orchards, and delaying year of heavy flowering.^{4/ 5/ 6/}

In 1968, an ad hoc Northwest Pollen Problems Committee was organized by researchers and seed orchardists to explore methods to control the inflow or the pollinizing effectiveness of outside pollen.^{7/} This paper reports on one of five new approaches suggested.

The assigned approach was to explore the possibility of carrying as much outside pollen as possible to the ground in a water spray. The senior author, noting that high elevation snowmelt was the water source for the orchard designated for the test, suggested that the primary intent of the study be changed to arresting development of the floral buds with very cold water. In earlier bud abortion studies, he had cooled individual branches for 10 days with melting ice and practically halted all shoot development for this period. If floral bud burst could be delayed by cold from a water spray as well as from evaporation through the 2-week period that most local pollen is released, contamination could be largely avoided. Orchard trees then could interpollinate in relative freedom from outside pollen. This report covers a low-cost exploration of this concept.

^{3/} Silen, Roy. Sampling of pollen contamination within Northwest seed orchards. IFA Tree Improvement Newsletter No. 7, pp. 5-13. Jan. 1968.

^{4/} See footnote 2.

^{5/} Silen, Roy R. Effect of altitude on factors of pollen contamination of Douglas-fir seed orchards. J. Forest. 61: 281-283, illus. 1963.

^{6/} Silen, Roy R. Pollen contamination and isolation. IFA Tree Improvement Newsletter No. 1, pp. 15-16. Nov. 1964.

^{7/} Silen, Roy R. Attempts at practical control of pollen contamination. (Abstr.) Proceedings of Western Forest Genetics Ass. meeting, Corvallis, Oreg. Aug. 1968.

MATERIALS AND METHODS

The water spray experiment was conducted at the U.S. Forest Service Heather Seed Orchard^{8/}--the only Northwest seed orchard with an ample supply of piped water in 1968. The 10-acre orchard is located at a 2,600-foot elevation on a high bench above Salt Creek, 15 miles east of Oakridge, Oregon. Salt Creek is a glaciated valley only a few miles from the crest of the Cascade Range, with canyon walls reaching 5,200 feet and forested with native Douglas-fir. Pollen contamination counts made in the orchard on 2 previous years indicated a high Douglas-fir pollen count of about 6,300 grains per square inch. Although the crop of floral buds on Douglas-firs around the orchard was heavy, flowering in the orchard was light but considered adequate for the study.

The study was designed with three paired 1/3-acre plots of about 100 trees, one sprayed and the other unsprayed in each pair. About equal numbers of ramets from each of the 15 clones were on each plot. This provided the opportunity to sample the same clones on each plot. Spraying began in the first 1/3-acre plot on March 18 (all buds tight), in the second plot on April 1 (floral buds swelling), and in the third plot on April 15 (10 percent of floral buds burst). Spraying continued until May 7 on all plots, providing a 6-, 4-, and 2-week spray period. The intent of the staggered dates was to bracket various portions of the growth period to see how many weeks of spraying might be required to achieve control over bud opening. Six overhead-type sprinklers were used on each sprayed plot. Although somewhat wasteful, these sprinklers produced enough spray below the arcing jet to maintain a film of water on all the plants during spraying without mechanical injury from the force of the jet.

Maximum temperatures were recorded among the foliage on each plot. Temperature records were also kept of water at the spray heads. Trees were sprayed whenever the air temperature exceeded 50° F.

From April 10 to May 15, pollen from surrounding forest stands was sampled in the orchard during dry weather periods on 64 vaseline-coated slides. Each faced one of eight compass points and was held at a 45° angle atop a 4-foot stake. Pollen was counted on five locations on each slide, each location was one-tenth inch on a side providing a 1/20-square-inch area sampled per slide.

^{8/} The authors gratefully acknowledge financial support for field phases of the study by Region 6, Forest Service, U.S. Department of Agriculture.

Twenty male and 20 female buds were observed for differences in stage of development twice a week on every plot. To estimate effectiveness of the water spray in reducing foreign pollen, we collected three female conelets from each plot on April 30 and May 7. Each conelet was dissected under a binocular microscope, and pollen grains were counted on every fourth scale. This method gave a direct estimate of amount of contaminating pollen. Significance of differences between pollen counts of conelets from corresponding clones on sprayed and unsprayed plots was tested by an analysis of variance.

On April 27, pollen from elongated catkins was collected in the sprayed plot to compare its viability with pollen from shedding catkins of the same clones in the unsprayed plot. Germination was tested within 2 hours of collection, by use of a 0.15-percent H_2O_2 test developed at the Forestry Sciences Laboratory at Corvallis.^{9/}

Other records taken included continuous temperature and humidity in a standard weather shelter, notes on the effectiveness of spraying, soil erosion, percent of buds unburst, pollen release of the male catkins, icing observations of orchard ramets during low temperature periods, and filled-seed count of sampled cones.

Spraying was halted May 7 when we observed that pollen shed was virtually complete on the trees surrounding the orchard. A heavy frost had occurred that night, killing most of the conelets in the orchard. Pollen was still shedding at higher elevations, so half the remaining conelets in the plots were enclosed in pollination bags that day to isolate them from external pollen. Cones that developed on the plots were collected on September 5, and counts of filled seed were recorded.

RESULTS

Despite frost damage that seriously reduced seed yield, the study showed considerable promise for use of cold water spray to slow floral development and reduce seed orchard pollen contamination.

Pollen density recorded in 1968 was extremely heavy. During the rain-free periods from April 10, when pollen was first observed, to May 17, an average of about 12,980 grains of Douglas-fir pollen per square inch was deposited on the vaseline-coated slides. This was

^{9/} This test has not been previously reported, although it has become widely employed for Douglas-fir by Northwest geneticists because of its rapid response. Its effectiveness has been verified by actual seed set data.

almost double the density of corresponding average counts of 6,338 and 6,234 made in the orchard during 1965 and 1966. Peak deposition in 1968 was on April 30 when 2,850 grains per square inch were deposited in a single 24-hour period. Production from the extremely light pollen crop within the orchard was a negligible part of this count.

Cold water spray markedly arrested but did not halt floral development. The influence on bud development by warm periods was obvious, even on sprayed plots. By May 7, plots sprayed on March 18 and April 1 were estimated to be 9.5 to 12.0 days behind the unsprayed control plots (table 1). Floral development was retarded as much by 4 weeks of spraying as by 6, indicating no advantage for the longer spraying period. Floral development on the plot sprayed for 2 weeks was delayed only 4.8 days, an indication that more than 2 weeks of spraying was necessary.

Development of female conelets on April 29 at peak of local pollen deposition illustrates the extent of retardation from the cold water spray. On that date, 70 percent of the 40 observed female buds on two control plots were open to receive pollen, compared with only 17.5 percent of 40 female buds on the two plots sprayed for 4 or 6 weeks.

Not only were male buds retarded from cold water spraying but no pollen was shed from opened male buds as long as spraying was continued. Even though more male buds had opened by May 7, wetness completely prevented shedding. Viability of pollen from water-sprayed male catkins tested just as high as from catkins on the unsprayed plots, both testing over 90 percent viable.

May 7 pollen counts on the female conelets provided a quantitative estimate of the level of control over contaminating pollen. Table 2, giving pollen counts on the three plots, shows maximum reduction of foreign pollen on the two plots where spraying began on April 1 and March 18. These dates were 2 and 4 weeks, respectively, ahead of local pollen release. Spraying begun on April 15 was too late to be as effective because female conelets were not delayed enough. Pollen counts on the female conelets of sprayed and unsprayed plots differed in the order of 18:1 for March 15, 36:1 for April 1, and only 3:1 for April 15. The differences between counts of sprayed and unsprayed plots were statistically highly significant ($F=47.97$ based on 1 and 24 d.f.). The reduction in pollen to levels generally below 100 grains per conelet by the longer spray periods, however, is the significant accomplishment since such levels of contamination are acceptable.

Cone yields were greatly reduced by extensive frost damage to cone buds. As buds opened on the unsprayed plots, there were four frosts with minimum temperatures from 28° to 26° F. Spraying preserved developing female conelets within the sprayed plots, but about 25 percent of the conelets were killed on unsprayed plots. Early on the morning of

Table 1.--Difference in stage of female conelet development on May 7
between control plots and plots sprayed with cold water

Stage of ♀ development	March 18 to May 7 (6 weeks)		April 1 to May 7 (4 weeks)		April 15 to May 7 (2 weeks)	
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed
	----- In percent -----					
Unburst	1/5	--	45	--	0	--
Burst (5)2/	15	--	10	--	10	--
Open (9)2/	80	--	30	--	15	--
Maximum (13)2/	--	5	15	10	75	25
Appressed (17)2/	--	75	--	70	--	60
Turning (20)2/	--	20	--	20	--	15
	----- In days -----					
Estimated delay in development3/	9.5		12.0		4.8	

1/ Basis is 20 ♀'s labeled for observation on each plot.

2/ Figures in parentheses represent normal lapsed developmental period in days to middle of stage. Data are from observations by senior author of average female bud development during two seasons at Corvallis, Oregon.

3/ From weighing numbers of ♀'s in each stage by normal day value for each stage.

Table 2.--*Pollen grains counted on scales of female conelets*^{1/}
on plots unsprayed and sprayed with cold water for
6, 4, and 2 weeks before May 7^{2/}

Spray period	Unsprayed plot (u)	Sprayed plot (s)	Ratios of grains per ♀ conelet
	<u>Number grains per ♀ conelet</u>		<u>Ratio u/s</u>
March 18 to May 7	1,391	77	18:1
April 1 to May 7	1,349	37	36:1
April 15 to May 7	2,164	733	3:1

^{1/} Each figure is the mean pollen count on 3 female conelets observed on May 7 when local trees had shed their pollen.

^{2/} Counts made on April 30 were similar but only about a third as high. Both were used in the analysis of variance cited in the text.

May 7, temperatures dropped to 26° F., killing most of the conelets in unsprayed plots and all but 29 in 6- and 4-week sprayed plots. No cones remained in the 2-week sprayed plot.

The 29 remaining cones, 14 of which were bagged on May 7, developed normally, proving that even 6 weeks of spraying did not alter subsequent cone or seed development. Cones were collected on September 5, and seed yields determined. Comparative seed yields are shown in table 3.

An 8- to 10-fold reduction in contaminating pollen thus is indicated from spraying. It was not possible to make comparisons representing the same clones in equal proportions nor to directly compare data by paired plots as we did with pollen sampled on conelets. Such clouds on the data are probably minor, the main shortcoming being the variance within small sample size left by the frost of May 7. For instance, on the sprayed plot, a single cone was observed with 27 filled seed, almost as many as were found in the other 13 of the 14-cone sample. A single such cone in so small a sample raised the percent seed set from a 2.2 average per cone to a 7.7 average and changed the comparison from an 18-fold to an 8-fold change due to cold treatment. The former figure approaches ratios indicated by earlier pollen sampling data.

Table 3.--Seed yields from trees on plots sprayed 6 and 4 weeks and from unsprayed control plots

Sample from	Number of cones	Number of seeds per cone	Range	Percent filled seeds per cone
Sprayed plots (bagged May 7)	14	4.1	0-27	7.7
Sprayed plots (not bagged)	15	22.4	2-40	44.0
Unsprayed orchard	26	41.1	14-87	64.8

The other 15 cones surviving the frost also developed, yielding an average of 22.4 seeds per cone. This indicates that subsequent pollination was effective for sprayed cones. It also indicates that considerable pollen from higher elevations was effectively reaching the orchard, a problem that is accentuated in narrow valleys but not considered serious for the majority of Northwest orchards which are located in extensive flat areas.^{10/}

Water temperatures at the sprayheads varied from 35° F. minimum to 48° F. maximum during the 6-week spray period. The rise occurred primarily when sun shown on the 700 to 1,000 feet of aluminum pipe needed to reach the plots. Leaf temperatures near the buds reached 56° F. even with continuous spraying on some hot days. Good insulation, or burying of the pipes, could have provided cooler water on the warmest days when conelet development was fastest. The floral buds, long held back by the cool water, developed appreciably in a 3-day warm period of April 27 through April 29, when afternoon temperatures reached 74° to 81° F.

Spraying gave some protection against frost damage as floral buds began to swell and open. No loss of cone buds occurred on the sprayed plots through four early frosts down to 26° F., whereas about a quarter of the unsprayed cone buds died in these frosts. However, protection by spraying was only negligible against the 26° F. frost on May 7 when buds were fully expanded. Records made on May 9 showed 70 percent of floral buds dead on unsprayed and 83 percent on sprayed

^{10/} See footnote 5.

plots. The entire 83-percent loss occurred on sprayed plots from the single 26° F. temperature, whereas only an estimated 45 percent died that night on unsprayed plots which had already had mortality from earlier frosts. Spraying might give important control of frost damage for the majority of seed orchards which are located at low elevations where late spring frosts seldom are as severe as 26° F.

About 20 percent of the ramets in the sprayed plot were severely bent or broken from the weight of a 1/2-inch ice coating formed from having the sprinklers on all night of May 6 to 7.

As the pollen counts were made, we observed that a watersoaked condition was common in the stigmatic area. We thought this might cause oxygen deficiencies and interfere with seed and pollen development; however, seed yields on cones from sprayed plots were higher than expected and watersoaking in stigmatic areas was not detrimental.

DISCUSSION AND CONCLUSIONS

The concept of slowing floral development by cold water appears the most promising of the many approaches explored to date toward practical control of pollen contamination in Douglas-fir seed orchards. Though some development occurred under treatment conditions of this study, female buds cooled by a water spray for a month prior to local pollen release remained in their scales long enough to reduce the amount of pollen contamination to a tolerable level. An even greater reduction might be possible if water temperatures are kept lower. Presumably, water temperature is the main variable. Evaporative cooling is another variable that might somehow be made more effective as well.

Expected adverse effects of continued wetting were not found. No soil erosion occurred in the seed orchard. Seed developed normally after 6 weeks of spraying. Pollen produced by ramets growing in sprayed plots appeared normal in germination tests. The spraying appeared beneficial in providing some frost protection but detrimental in causing some ice damage during severe frosts.

A serious limitation of this approach is that no other orchard in the Northwest now has an adequate supply of cold water. Prodigious amounts of water would be required to spray large orchards with overhead-type sprinklers for a 4-week period. However, water needs might be reduced through use of intermittent mists or fine sprays. Such reduced needs might be met with well water, which is usually in the 40° to 50° F. range during this period.

As with agricultural crops, artificial control of microenvironments on a commercial scale, such as this concept represents, will probably require an extensive developmental effort. These results encourage such an effort.

PNW-102

April 1969

SEQUENTIAL SAMPLING OF DOUGLAS-FIR
TUSSOCK MOTH POPULATIONS

by

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Insect Ecologist



ABSTRACT

Sequential plans have been constructed for sampling eggs and larvae of the Douglas-fir tussock moth. The plans are a standardized method for making quick ground surveys of incipient outbreaks. They are designed to be applied independently at selected points in an suspected infestation for distinguishing currently innocuous populations from those having outbreak potential. The sequential schemes are recommended primarily for sampling tussock moth larvae in the early instar.

INTRODUCTION

The Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McDunnough, is an important defoliator of Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco and the true firs, *Abies* spp. Tussock moth outbreaks have a history of developing unexpectedly. Often the sudden appearance of defoliated trees may be the first indication of an infestation. Immediately prior to an outbreak, when defoliation is not yet evident, the incipient infestation is sometimes difficult to detect. However, on careful examination, larvae are often fairly common in the foliage of many trees. On the other hand, conspicuous feeding on a few trees, although it may indicate a local population center, does not

necessarily portend a general outbreak the following year. In these situations, extensive ground surveys are needed that will give a standard quantitative assessment of populations over the whole suspected area.

Sequential sampling is a rapid and systematic way of evaluating populations in incipient outbreaks. Because population levels are classified into general categories, sequential sampling requires much less time than is needed for precise population estimates. The methods described in this paper are especially useful for making rapid surveys around newly discovered spots that may require early control action. The sequential schemes were constructed so that low populations with little chance of increasing to a destructive level in 1 year can be quickly distinguished from higher populations that seem to have outbreak potential.

Field methods for precisely estimating the size of tussock moth populations from a fixed number of tree samples have been developed and are reported in another paper.^{1/} In sequential sampling, identical techniques are used for taking foliage samples from the tree; however, the number of trees to be examined to classify a population is variable. The data used in developing the sequential sampling methods in this paper were gathered largely from tussock moth infestations in white fir, *Abies concolor* (Good. and Glend.) Lindl., and may not be representative of infestations in other tree species.

THE SAMPLE UNIT

The basic sample unit is a collection of twigs or branches, called subsamples, taken representatively from a tree. Twigs are used for sampling larvae and whole branches for sampling egg masses. The arrangement of subsamples needed to represent the crown correctly depends on which stage of the insect is being sampled. Recommended procedures for sampling foliage are given on pages 5 and 6 for larvae and page 8 for egg masses.

Population size is the density of insects per 1,000 square inches of branch area. Branch area is the square inches occupied by foliage on a twig or branch, estimated by the foliated length measured along the stem and multiplied by one-half the maximum width of foliage on the twig or branch. For determination of insect density, the number of egg masses

^{1/} Mason, Richard R. Development of sampling methods for the Douglas-fir tussock moth, *Hemerocampa pseudotsugata* (Lepidoptera: Lymantriidae). 1969. (In preparation for publication by Pacific Northwest Forest & Range Exp. Sta., Forest Serv., U.S. Dep. Agr., Portland, Oregon.)

or larvae on the subsamples is related to total branch area of the sample unit and then corrected to a uniform area of 1,000 square inches as follows:

$$\text{Number of larvae (or egg masses) per 1,000 sq. in.} = \frac{\text{Total larvae (or egg masses) on subsamples}}{\text{Total branch area (sq. in.) of subsamples}} \times 1,000$$

CONSTRUCTING THE SEQUENTIAL PLANS

Basic requirements for development of a sequential sampling plan are: (1) knowledge of the frequency distribution of the insect population and (2) the biological significance of different size populations for setting class limits. Previous work shows that tussock moth populations conform to a negative binomial distribution.^{2/} Setting class limits depends on the type of information wanted for the population in question.

Classes for the sequential schemes given in this paper were established primarily for separating low, insignificant populations from larger populations which seem to have the numerical potential for rapidly expanding into an outbreak. This two-class scheme allows for the quickest possible classification of a population. Normally, these class limits are below the level at which defoliation is readily discernible from aerial observation; therefore, the calculated plans are essentially a technique for ground detection and appraisal of incipient infestations. Class limits for the plans are:

Light population (outbreak not imminent) = 10 or less first-instar larvae or eggs per 1,000 sq. in. of branch area.

Heavy population (outbreak imminent) = 20 or more first-instar larvae or eggs per 1,000 sq. in. of branch area.

For establishing class limits, eggs instead of egg masses are used because they are more comparable to larvae on a numerical basis. Although egg masses are the units counted in the field, the number of eggs in the masses is the major interest and, therefore, is the value on which the sequential plan is built. Later, a conversion to egg masses is made for field use based on the number of eggs in an average mass.

^{2/} See footnote 1.

Formulae for the calculation of decision lines used in constructing the sequential plans have been published by Waters.^{3/} The parameter, k , a coefficient reflecting aggregation in the negative binomial distribution, is in the formulae and has a great effect on the slope and spacing of the decision lines used to construct the sequential plan. A small k implies a high degree of aggregation and a large k , low aggregation.

Common k values have been calculated from field data for larvae and eggs.^{4/} Larvae have a k value of 2.358 and eggs a value of 0.425. The relatively low k for eggs is due to the high aggregation of eggs in masses, whereas the value for larvae is large because they are more dispersed through the tree foliage. Decision lines for the calculated sequential plans are shown in figures 1 and 2. Lines are plotted for

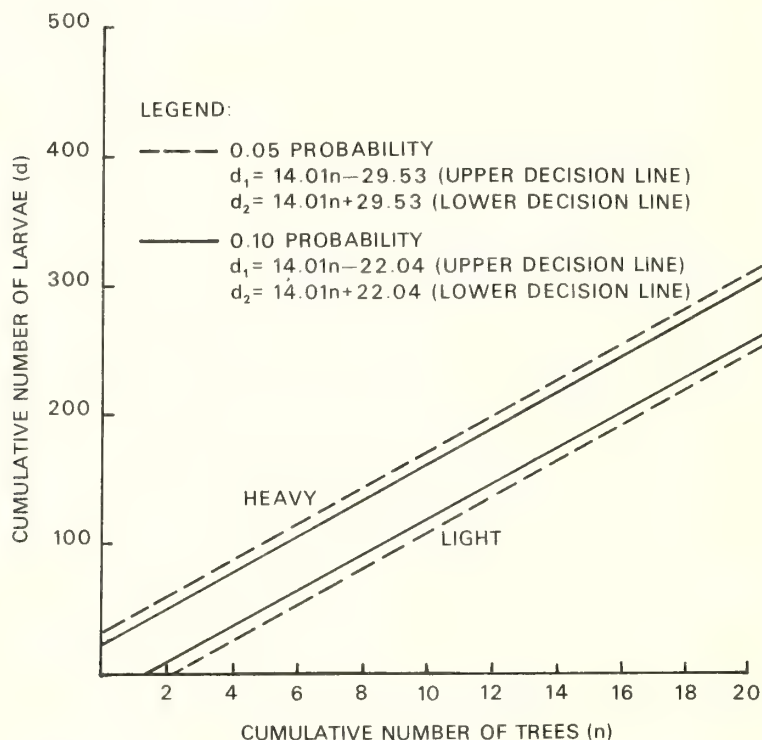


Figure 1.--Sequential graph for classifying Douglas-fir tussock moth larvae into two population levels.

^{3/} Waters, W. E. Sequential sampling in forest insect surveys. Forest Sci. 1: 68-79. 1955.

^{4/} See footnote 1.

two confidence levels for the α and β errors inherent in a sequential sampling plan.^{5/} The lines for eggs are much wider apart than they are for larvae, which means that more sampling is needed to reach a decision for eggs than for larvae. Therefore, populations can usually be classified quickest by sampling the larval stage.

PROCEDURES FOR SEQUENTIAL SAMPLING OF LARVAE

Tussock moth larvae in the midcrown of the tree are consistently representative of larval density over the whole crown; therefore, only this portion of the crown needs to be sampled.^{6/} The midcrown itself can be sampled representatively by taking three foliated twig samples about 17 inches long in a 1:2 combination, respectively, from the

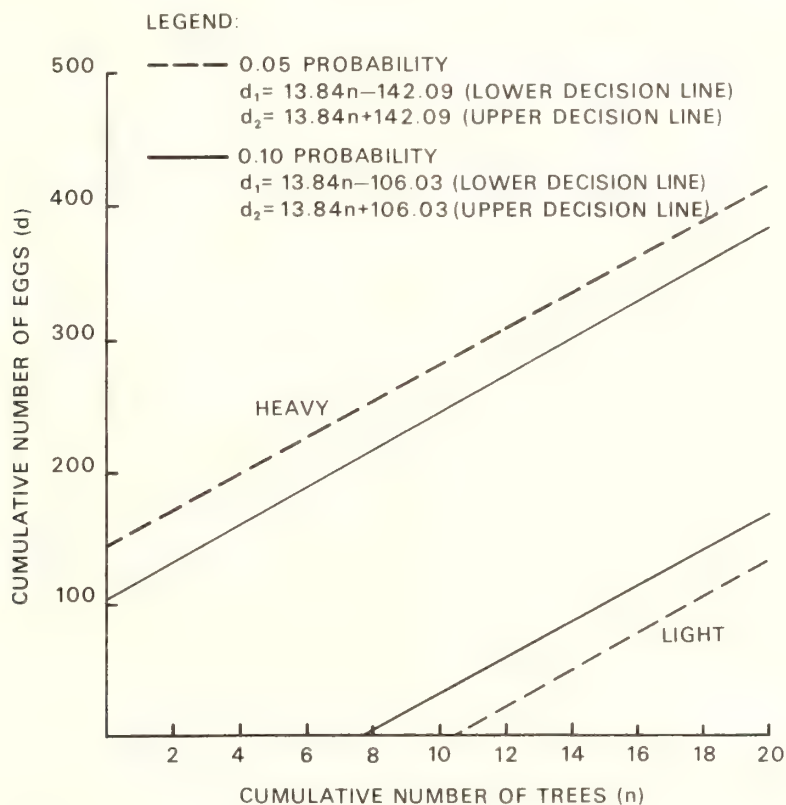


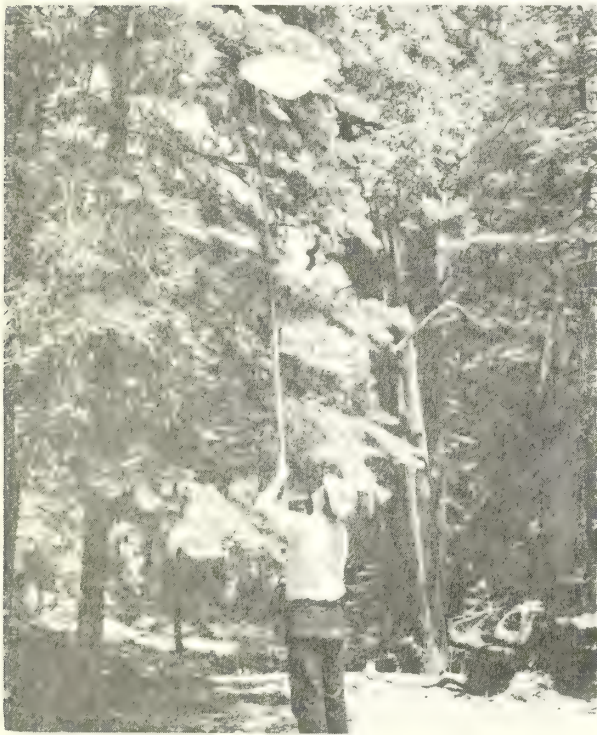
Figure 2.--Sequential graph for classifying Douglas-fir tussock moth eggs into two population levels.

^{5/} See footnote 3.

^{6/} See footnote 1.

outside and inside portion of the midcrown. The outside crown is defined as the outer 17 inches at the end of the main branch; the inside crown is all foliage on side branches at least 17 inches in from the end of the main branch.

Twig samples can be clipped from the tree with a pole pruner and collected in a cloth basket attached to the end of the pole just below the cutting head. Special care should be taken not to disturb the twig or other foliage on the tree before it is clipped lest agitated larvae drop from the sample before it is secure in the basket. Larvae can be dislodged for counting if the sample is held over a white cloth on the ground and rapped sharply with a stick (fig. 3). After larvae have been counted on all three twigs, their density per 1,000 square inches of branch area can be calculated (see page 3).



A



B



C

Figure 3.--Field sampling of tussock moth larvae: A, pole pruner with attached basket for clipping twig subsamples from tree; B, rapping twig to dislodge larvae; C, measuring twig to determine branch area.

In table 1, sequential data are compiled for field use, giving the number of trees and larvae needed to classify a population at different confidence levels. Larval density values are accumulated from sample trees until: (1) the cumulative total is equal to or less than the stipulated total in the "light" column for the number of trees sampled, in which case the population is classified as light;

Table 1.--*Sequential plan for classifying Douglas-fir tussock moth larval populations, by two levels of confidence*^{1/}

Number of trees	Cumulative total of number of larvae per 1,000 sq. in.			
	0.1 confidence level		0.05 confidence level	
	Light	Heavy	Light	Heavy
1	--	37	--	44
2	5	51	--	58
3	19	65	12	72
4	33	79	26	86
5	47	93	40	100
6	61	107	54	114
7	75	121	68	128
8	89	135	82	142
9	103	149	96	156
10	117	163	110	170
11	131	177	124	184
12	145	191	138	198
13	160	206	152	212
14	173	219	166	226
15	187	233	180	239
16	201	247	194	253
17	216	261	208	268
18	229	275	222	282
19	243	289	236	296
20	257	303	250	310

^{1/} Larvae are counted on three twigs, sampled in a 2:1 combination, respectively, from the inside and outside of the middle crown of each tree. Sampling should continue as long as cumulative total falls between counts listed in "light" and "heavy" columns.

or (2) the cumulative total is equal to or more than the total in the "heavy" column, in which case the population is classified as heavy. As long as the cumulative total falls between the "light" and "heavy" columns, sampling continues.

A special tally sheet (fig. 4) can be prepared which will greatly facilitate the use of the sequential scheme during the actual survey. The sequential plan is written in the squares across the top of the columns and gives the upper and lower limits of cumulative values needed to reach a decision on classification. The upper left corner gives the upper limit for a light population and the lower right corner the lower limit for a heavy population. As trees are sampled, the insect density values are accumulated and recorded in the square across the page opposite the sample point that is being examined and beneath the appropriate tree taken in sequence. When the cumulative total sampled is equal to or less than the specified limit in the upper left corner of the overhead box, sampling is terminated and the point is classified light. If the cumulative total is equal to or more than the limit in the lower right corner of the box, the point is classified heavy.

PROCEDURES FOR SEQUENTIAL SAMPLING EGGS

In low-level populations, egg masses of the tussock moth are found in almost any part of the tree crown. Until further work is done to establish a portion of the crown that may be a reliable indicator of the egg population over the whole tree, the entire crown must be sampled. For a representative sample, four whole branches should be taken in a 1:2:1 combination, respectively, from the upper, middle, and lower crown. These areas of the crown are defined as the foliated branches stemming from the upper, middle, and lower thirds of the tree bole. Egg masses on the four whole branches are counted and their density per 1,000 square inches of branch area is calculated.

Field plans for sequential sampling of eggs are given in table 2. To facilitate the use of the table in the field, the number of eggs in figure 2 was converted to egg masses by dividing by 260, the approximate number of eggs per mass in a low-level population.^{7/} If there is reason to believe that the average number of eggs per mass in the area to be evaluated differs significantly from 260, the factors may have to be corrected by presampling egg masses, and a new field table will need to be compiled. However, in relatively low populations, for which this sequential plan has been constructed, a value of 260 eggs per mass is probably appropriate. In high populations, where overcrowding might affect fecundity, the conversion value could be much smaller.

^{7/} See footnote 1.

Location _____

Date _____

Cumulative Number of Trees

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Point No.	L H	5 51	19 65	33 79	47 93	61 107	75 121	89 135	103 149	117 163	131 177	145 191	160 206	173 219	187 233
1															
2															
3															
4															
5															
6															
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19															
20															

Figure 4.--Sample form sheet for tallying larvae in field at a confidence level of 0.10.

Egg mass densities are accumulated from consecutive trees until a decision is reached on light or heavy populations in the same manner as described for larvae. It can be seen in the sample plan in table 2 that at the 0.1 confidence level, a minimum of eight trees with no egg masses have to be sampled before a "light" decision can be reached;

Table 2.--*Sequential sampling plan for classifying Douglas-fir tussock moth egg populations, by two levels of confidence*^{1/}

Number of trees	Cumulative total of number of egg masses per 1,000 sq. in.			
	0.1 confidence level		0.05 confidence level	
	Light	Heavy	Light	Heavy
1	--	0.46	--	0.60
2	--	.52	--	.65
3	--	.57	--	.71
4	--	.62	--	.76
5	--	.67	--	.81
6	--	.73	--	.87
7	--	.78	--	.92
8	0.02	.83	--	.97
9	.07	.88	--	1.03
10	.12	.94	--	1.08
11	.18	.99	0.04	1.13
12	.23	1.04	.09	1.18
13	.28	1.10	.15	1.24
14	.34	1.15	.20	1.29
15	.39	1.21	.25	1.35
16	.44	1.26	.30	1.40
17	.50	1.31	.36	1.45
18	.55	1.37	.41	1.50
19	.60	1.42	.47	1.56
20	.66	1.47	.52	1.61

^{1/} Egg masses, assumed to contain an average of 260 eggs per mass, are counted on four whole branches, sampled in a 1:2:1 combination, respectively, from the upper, middle, and lower crown of each tree. Sampling should continue as long as cumulative total falls between counts listed in "light" and "heavy" columns.

conversely, a mean egg mass density of only 0.46 per 1,000 square inches on the first sample will give a classification of heavy for that point. This occurs because of the large number of eggs in a single mass which greatly increases the probability of a population being over 20 insects per 1,000 square inches.

USING SEQUENTIAL PLANS FOR A SURVEY

To evaluate a population in a potential outbreak, numerous sample points need to be visited over the area from which population information is desired. The spacing of sample points depends entirely on the intensity with which the area needs to be surveyed. The sequential sampling plan is applied independently at each point. A sample point should consist of approximately 1 acre where trees are randomly selected and sampled until the population at the point can be classified as either light or heavy. After a number of sample points have been classified, infestation patterns in the area will probably become apparent and can be delineated on a map.

The light and heavy infestation classes have been based on numbers of eggs or first-instar larvae. Therefore, for effective use of these classes, timing of the larval sample is critical because numbers decline sharply after larvae are hatched. If older larvae are sampled, the classification schemes as designed become less meaningful.

In endemic populations, there will be a much higher probability of sampling young larvae which are dispersed in the foliage than of sampling eggs that are aggregated in masses. This fact is reflected in the sequential plans which stipulate that considerably less sampling is required to classify larval than egg populations. For this reason, extensive surveys for detection in low-level situations will be most efficient if they are timed to sample the easier found early-instar larvae. Surveys at that stage should be reasonably comparable to egg surveys, but they can be performed at the same precision with considerably less work. Moreover, the number of first-instar larvae may actually be a more realistic value for the population than eggs, because parasitized and nonviable eggs would not affect the estimate.

PNW-103

April 1969

INFLUENCE OF SITKA ALDER ON SOIL FORMATION AND
MICROBIOLOGICAL SUCCESSION ON A LANDSLIDE
OF ALPINE ORIGIN AT MOUNT RAINIER

by

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K. C. Lu, *Microbiologist*
J. M. Trappe, *Principal Mycologist*
and
R. F. Tarrant, *Principal Soil Scientist*



ABSTRACT

A Sitka alder seedling, growing on 5-year-old avalanche debris below Mount Rainier, led to increased soil carbon and nitrogen and increased microbial populations over a 3-year period. Over 5 years, avalanche debris decreased in pH from moderately alkaline to slightly acid, and the "soil" surface had become somewhat more consolidated.

The debris and rock, deposited below Emmons Glacier by the 1963 avalanche from Little Tahoma Peak, was first sampled in October 1965 for chemical and microbial analysis.^{1/} The samples were extremely low in available nutrients and numbers of micro-organisms as compared with samples from under a clump of Sitka alder (*Alnus sinuata* (Reg.) Rybd.) on an adjacent terminal moraine disgorged by the glacier in 1897. Although only meager amounts of carbon and nitrogen were present in the top 8 inches of the 2-year-old avalanche material, corresponding values for the moraine soil indicated appreciable organic matter from the Sitka alder and its associated mosses and lichens.

^{1/} Bollen, W. B., Lu, K. C., Trappe, J. M., Tarrant, R. F., and Franklin, J. F. Primary microbiological succession on a landslide of alpine origin at Mount Rainier. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Res. Note PNW-50, 7 pp., illus. 1967.

We intend to follow development of soil and microbiological succession on the Little Tahoma deposit. To plan timing of the next major sampling, we collected interim soil samples in September 1968, nearly 5 years after original deposit (fig. 1). Methods were the same as in 1965 and sampling sites were comparable, though fewer. In addition, three subsamples, later composited, were taken from immediately around the roots of a 3-year-old Sitka alder that had become established since the 1965 sampling on the new "soil" about 10 meters southwest of the adjacent terminal moraine. This alder had a nodule cluster 3 centimeters in diameter at its root collar. Soil samples were collected, prepared, and analyzed by the methods previously described.^{2/}

Results show a striking increase of total carbon, nitrogen (obtained by the Kjeldahl method), ammonium, and, to a minor degree, nitrate under the young alder (table 1). Molds, mostly *Penicillium* sp., were much more numerous near the seedling roots, and numbers of bacteria and percent of *Streptomyces* sp. were nearly double those found in the sample taken about 5 feet from the alder seedling. Compared with 1965 samples of unvegetated debris, this material outside the influence of alder contained twice as much Kjeldahl nitrogen and some ammonium and nitrate nitrogen not detected previously.

During the 3 years between samplings, the pH decreased by two units. From moderately alkaline in 1965, the material changed to slightly acidic in 1968, a drop in

^{2/} See footnote 1.



Figure 1.--The avalanche surface was still mostly unvegetated in 1968. Emmons Glacier and Little Tahoma Peak, the source of the avalanche, are in the background.

Table 1.--Chemical, microbial, and mechanical analyses of samples from
Little Tahoma avalanche deposits near adjacent moraine; on
oven-dry basis

Sample analysis	1965 sample <u>2</u> ^{1/}	1968	
		Sample 1, away from alder ^{2/}	Sample 2, around 3-year-old alder roots
Detritus.....percent..	87.3	39.3	50.9
-10 Mesh.....grams..	94.0	649.0	469.0
Water.....percent..	10.6	8.7	9.9
pH	8.7	6.7	6.7
Nitrogen:			
NH ₄ ⁺ parts per million..	(<u>3</u> /)	2.0	35.0
NO ₂ ⁻ parts per million..	(<u>3</u> /)	<.1	<.1
NO ₃ ⁻ parts per million..	(<u>3</u> /)	.9	1.5
Kjeldahl.....percent..	.002	.004	.009
Total carbon.....percent..	.049	.036	.057
C:N ratio	25:1	9:1	6:1
Molds:			
Total.....thousands per gram..	.16	.40	20.5
Penicillia.....percent..	50.0	95.0	100.0
Mucors.....percent..	0	3.0	0
Bacteria:			
Total.....thousands per gram..	37.5	92.5	182.0
Streptomyces.....percent..	16.0	17.0	33.0
Mechanical analysis (-10 mesh):			
+20.....percent..	27.74	15.64	16.40
+40.....percent..	19.28	25.26	36.08
+60.....percent..	7.73	13.03	9.72
+80.....percent..	7.31	10.59	5.84
+100.....percent..	4.59	5.74	3.95
+150.....percent..	7.13	6.80	5.69
+200.....percent..	5.33	4.38	4.37
-200.....percent..	20.85	18.56	17.95
Total	99.96	100.00	100.00

^{1/} Near lower edge of main deposit.

^{2/} Location comparable to sample No. 2, 1965.

^{3/} None detected.

pH that can be attributed to intensive leaching. Ugolini^{3/} found a similar but less rapid change of alkaline, uncolonized, unweathered glacial till in Alaska; under contiguous 17-year-old alder (*A. incana* (L.) Moench), the pH dropped to 6.8. Alder, in addition to enriching rocky debris with organic matter and nitrogen, depletes it of carbonates and progressively acidifies it.

The mechanical analyses are not readily interpretable because the avalanche material was extremely heterogeneous. However, in 1968 there was indication of decrease in amount of the coarsest material (+20 mesh) and increase in the next two smaller sizes. It was also evident that the avalanche surface was more compacted than in 1965. Progressive textural differences in soil developing on till have been ascribed by Ugolini^{4/} to surface washing, frost mixing, and mechanical segregation as well as to variations in the original parent material. In the case of the Little Tahoma avalanche, a factor contributing further to the proportional increase in fine materials was deposition from adjacent moraines and pumice deposits by strong winds which sweep the slopes of Mount Rainier (fig. 2).



Figure 2.--Dust and fine sand are blown onto the avalanche surface from adjacent moraines and pumice deposits by the strong winds that frequently blow about Mount Rainier.

^{3/} Ugolini, F. C. Soil development and alder invasion in a recently deglaciated area of Glacier Bay, Alaska. *In* Biology of alder, J. M. Trappe, J. F. Franklin, R. F. Tarrant, and G. M. Hansen (eds.). Northwest Sci. Ass. Fortieth Annu. Meeting, Symp. Proc. 1967:115-140, illus. 1968.

^{4/} See footnote 3.

The influence of invading alder on soil formation in this raw avalanche deposit was strikingly shown by results from this interim sampling. It further confirms Mitchell's^{5/} conclusions on the importance of Sitka alder as a colonizer that builds nitrogen content and organic matter of soils on recently glaciated terrain of coastal regions of Alaska.

^{5/} Mitchell, W. W. On the ecology of Sitka alder in the subalpine zone of south-central Alaska. *In* Biology of alder, J. M. Trappe, J. F. Franklin, R. F. Tarrant, and G. M. Hansen (eds.). Northwest Sci. Ass. Fortieth Annu. Meeting, Symp. Proc. 1967:45-56, illus. 1968.

PNW-104

April 1969

EFFECT OF GRAFT TYPE ON 6-MONTH SCION SURVIVAL
OF FIELD GROWN DOUGLAS-FIR GRAFTS

by

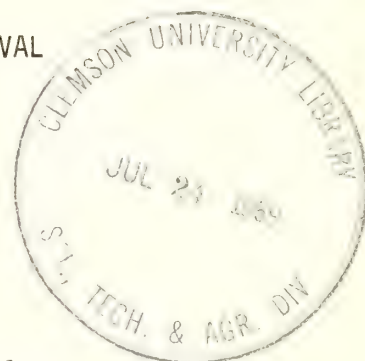
Donald Copes, Plant Geneticist

ABSTRACT

A study on field survival after 6 months of top-cleft, splice, and side grafts revealed that graft type and technique were not significant sources of variation when 80 mm. or more of cambial contact connected the stock and scion.

Thousands of grafts are made each year to establish and maintain Douglas-fir seed orchards. A number of different graft types are used. Each orchardist soon adopts or devises the graft type that he assumes to be the best, easiest, or quickest to make. If use of one graft type can be shown to consistently result in higher 1st-year survival, considerable dollar savings can be made each year. It has been previously reported that 1st-year graft survival in Douglas-fir grafts was closely correlated with length of cambial tissues shared between the stock and scion.^{1/} Length of cambial tissue varied between graft types, so role of graft type on 1st-year survival could not be assessed. The following report presents results of a subsequent experiment designed to investigate graft type influence on early survival.

^{1/} Copes, Donald L. 1967. Influence of cambial contact length on graft survival and leader elongation in Douglas-fir. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Res. Note 69, 8 pp., illus.



METHODS

Grafting technique, location, and age of rootstock, graft position on the stock, and time of year of grafting were the same as described for the 1966 grafts (see footnote 1). These details are not considered to have enough influence on the outcome of the study to warrant repetition. Each graft type was cut with 40 and 80 mm. of cambial contact, whereas cambial contact in the 1966 study varied between graft types from 23 to 256 mm. In addition, only three types--top-cleft, side, and splice (fig. 1)--were made, rather than seven types.

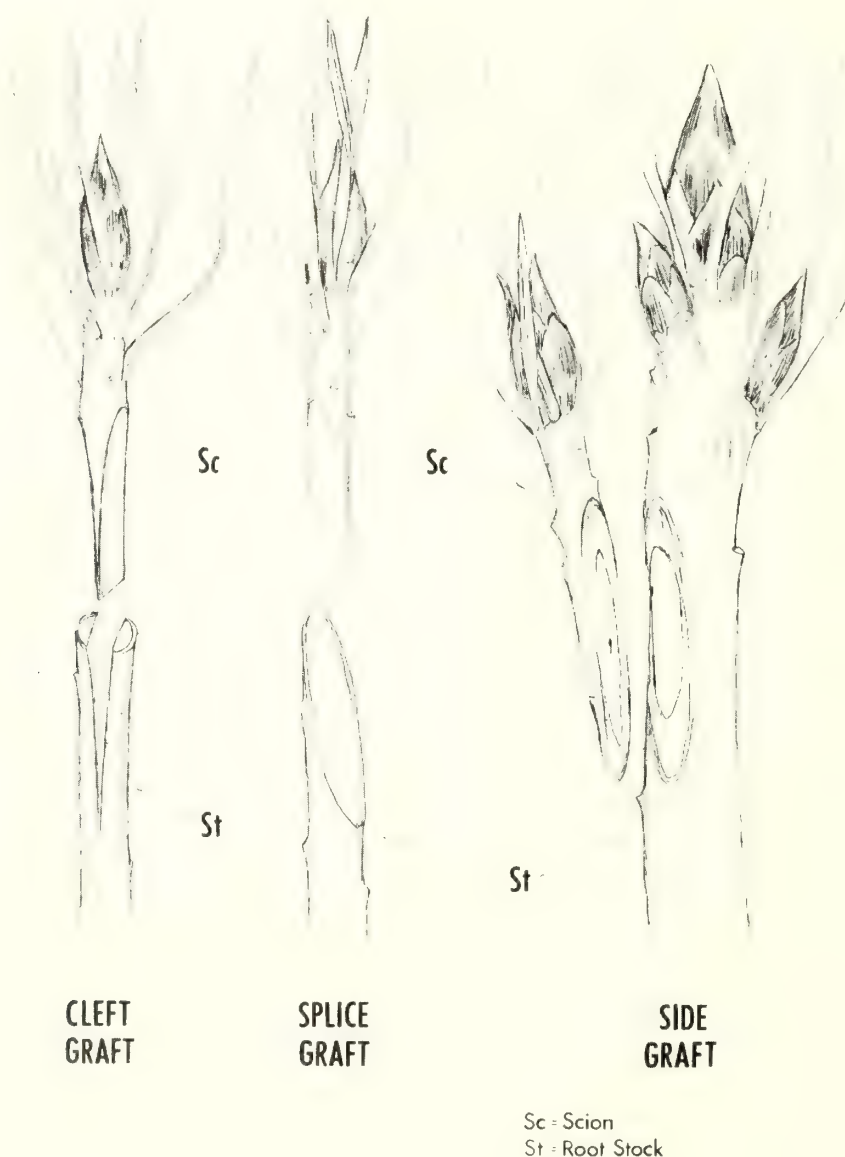


Figure 1.--Stock and scions prepared for the top-cleft, splice, and side graft types.

Poor grafting technique (mismatched treatment) was simulated by matching only one longitudinal surface of the scion with one cambial surface of the rootstock. Each mismatched graft had all of its 40 or 80 mm. of cambial contact on the one matched surface. Good grafting technique (matched treatment) was simulated by matching both longitudinal cambial surfaces of the scion with the two cut surfaces of the rootstock. Forty- and 80-mm. matched grafts had 20 and 40 mm., respectively, of cambial contact on each side.

In 1967, 20 grafts of each graft type--top-cleft, side, and splice--were cut with 80 mm. of cambial contact. Within each graft type, 10 grafts had two matched cambial surfaces and 10 had only one matched cambial surface. In 1968, 40 grafts of each graft type were cut to 80 mm. of contact and another 40 grafts of each type were cut to 40 mm. of contact. Within each combination of graft type and cambial contact length, 20 grafts were made with the matched cambiums and 20 with the mismatched cambiums. We recorded 6-month survival in mid-September after all growth had ceased.

RESULTS

Survival for each graft type and length of cambial contact are given in table 1. Survival of the 80-mm. grafts of all three types was 97 percent in 1967 and 1968, but survival of the 40-mm. grafts in 1968 was 82 percent. This difference between the 40- and 80-mm. grafts was significant at the 0.05 level. A significant difference between matched and mismatched cambial aligned grafts was not found in the 80-mm. grafts, but the difference between matched and mismatched 40-mm. grafts was significant at the 0.05 level. The 40-mm. mismatched grafts had a survival value of 92 percent, but 40-mm. matched grafts had 73-percent survival, an unexpected result to be subsequently discussed.

At 80 mm. of cambial contact, graft type did not significantly influence survival in 1967 or 1968. Greater variation due to graft type was exhibited at 40 mm. than at 80 mm. Matched splice grafts averaged only 65 percent, but matched side and cleft grafts had survivals of 75 and 80 percent, respectively. Within all three graft types, the 80-mm. grafts survived better than 40-mm. grafts (table 1).

DISCUSSION

Graft type had greater influence on survival when cambial contact was limiting (40 mm.) than in 80-mm. grafts in which all three graft types had high survival. In matched grafts at 40 mm., cleft grafts had 15-percent-higher survival than splice grafts. The cause of this variation is not known, but improper alignment of the cambial edges is probably more critical at short cambial lengths. As is apparent in

Table 1.--Survival percent 6 months after grafting by graft type, and length and alignment of stock-scion cambial contact, 1967 and 1968 grafts

Graft type	1968 grafts						1967 grafts, 80-mm. length		Graft type means	
	40-mm. length		80-mm. length							
	Mismatched	Matched	Mismatched	Matched	Mismatched	Matched	80 mm.	40 mm.		
Cleft	1/95	1/80	1/100	1/100	2/100	2/100	100	87		
Side	95	75	95	95	90	100	95	85		
Splice	85	65	100	95	90	100	97	75		
Mean	92	73	98	97	93	100	97	82		
Mean	82		97		97					

1/ Percentages based on 20 graft samples.

2/ Percentages based on 10 graft samples.

figure 1, the two straight cambial zones of the cleft graft may be easier to match exactly than the curved zones of the splice and side grafts. Lack of a perfect stock-scion fit within the matched and mismatched grafts would reduce the length of cambial contact to less than 40 mm. and may have a greater effect on survival than a similar reduction in an 80 mm. graft.

Higher survival of the 80-mm. than the 40-mm. grafts was as expected (see footnote 1), but the difference between the 40-mm. matched (73 percent) and mismatched (92 percent) grafts was unexpected. Mismatched grafts survived much better than they should have considering their length of cambial contact. Figure 2 of the 1966 study (see footnote 1) indicated that about 93-percent and 67-percent survival should have occurred for 80- and 40-mm. grafts, respectively. An examination of the unions in September 1968 revealed that most 40-mm. mismatched grafts had healed across both the 40-mm. matched surface and the 40-mm. mismatched surface, and had actually formed 80-mm. matched grafts rather than the 40-mm. mismatched grafts. Healing of the 40-mm. mismatched surface occurred because an abnormally cool, wet spring following grafting resulted in a longer than normal period for union establishment. Healing of much of the additional 40 mm. of mismatched surface explains why the so-called 40-mm. mismatched grafts survived almost as well as the 80-mm. grafts. The same situation could not prevail for 40-mm. matched grafts because the cut surfaces totaled only 40 mm.; no additional surface was available for further union development. Thus, only the matched 40-mm. grafts present survival data for grafts with just 40 mm. of cambial contact, in which case the 73-percent survival is close to the 67-percent survival of the 1966 grafts.

A healing of the mismatched surface occurred in the mismatched 80-mm. grafts and resulted in many grafts having between 80 and 160 mm. of cambial contact rather than the desired 80 mm. In this case, little additional survival occurred because 80 mm. was already adequate cambial contact for high survival; the additional cambial contact over 80 mm. was merely surplus.

CONCLUSION

Three graft types--top-cleft, splice, and side grafts--were made with each graft having 40 or 80 mm. of cambial contact shared between the stock and scion. Only 73 percent of the grafts that actually had 40 mm. of cambial contact survived 6 months, and 97 percent of the 80-mm. grafts were alive. Field survival data indicated that graft type and grafting technique were not significant sources of survival variation when at least 80 mm. of cambium connected the stock and scion.

PNW-105

May 1969



RIPENING AND DISPERSAL OF A
BUMPER WESTERN HEMLOCK-SITKA SPRUCE
SEED CROP IN SOUTHEAST ALASKA

by

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Institute of Northern Forestry

ABSTRACT

During a bumper seed year, a mature western hemlock-Sitka spruce stand in southeast Alaska produced 131 pounds of seed per acre, 63 percent of which was sound. Seed was dispersed over a 1-year period beginning on October 22, with cone scales opening and closing in response to moisture, and seedfall increased by wind. Information on cone condition, seed ripening, and weather conditions associated with seed dispersal is given.

Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) together comprise about 92 percent of the commercial timber volume in southeast Alaska. Both species are prolific seed producers, with at least some seed produced almost every year and a heavy crop every 5 to 8 years. Seed dispersal from the heavy cone crops of 1951 and 1959 and from the medium cone crop of 1956 has been reported (Godman 1953; Harris 1967; James 1959).^{1/} In 1966, a bumper cone crop occurred, offering an opportunity to obtain more detailed information about seed maturation and its dispersal.

^{1/} Names and dates in parentheses refer to Literature Cited, page 11.

Seeds of both hemlock and spruce are small, hemlock averaging 297,000 seeds per pound and spruce 210,000 seeds per pound (U.S.D.A. Forest Service 1948). Seeds of both species have large wings for their weight and are carried great distances by the wind. This has led to the practice in southeast Alaska of clearcutting timber in blocks up to a mile square and relying on natural seedfall to restock the cuttings. Reliance on natural regeneration, seed collecting for provenance testing, and the expectation of future intensive silviculture led us to this investigation of seed production and dispersal.

METHODS

The study was done in an old-growth, western hemlock-Sitka spruce stand located 4.5 miles northwest of Juneau, Alaska. Timing and amount of natural seedfall was determined from four seedtraps, each 2 by 3 feet in size, located in a line 2 chains apart beneath the timber stand. The stand, as characterized by a circular 1/5-acre plot surrounding each seedtrap, averaged 88 trees per acre. Average tree diameter at breast height was 21 inches, ranging from 8 to 40 inches. Dominant trees were 130 feet tall. Basal area was 248 square feet per acre, and species composition by basal area was 74 percent hemlock, 26 percent spruce.

Seedtraps were inspected daily from October 1966 through January 30, 1967, then monthly or intermittently through December 1967. Muslin liners were removed at each inspection and seed were counted. A cutting test was made to determine seed soundness at monthly intervals.

For determining when seed ripened (matured), cones were collected from one mature spruce and one mature hemlock tree at weekly intervals from July 30 to October 15, 1966. Cones were collected from the top one-third of tree crowns by use of 40-foot aluminum ladders attached to the boles for easy access to branches. Three to five cones were dissected immediately after collection. Cone scale color and seed color, interior consistency, and wing condition were described.

Ten spruce and 20 hemlock cones were measured, then air-dried at room temperature immediately after collection. Seed was extracted and stored dry at 40° F. until all collections had been completed. In most cases, cones opened from one to several days after drying began, and seed was easily shaken out. However, both the hemlock and spruce cones collected on July 30 failed to open and had to be cut apart to remove seed. Viability was then determined from germination tests of four lots of 50 seeds each.

On January 31, seeds were placed on germination pads in covered petri dishes and maintained at 75° to 80° F. and 12-hour-day light periods until April 26. A seed was considered to have germinated when the radicle emerged.

Weather data for the general area was obtained from published records of observations made at the ESSA-Weather Bureau Office at the Juneau Municipal Airport, located 3.5 miles northwest of the study area.

RESULTS

Seed Ripening

Germination tests showed that some spruce seed was mature enough to germinate by August 6 and viability increased abruptly during the week of August 13-20. Maximum maturity appears to have been reached by September 3 with no increase thereafter, although test results were erratic. Spruce seed began to mature when about 1,000 degree-days^{2/} had accumulated (fig. 1). Greatest increase in maturity occurred between 1,000 and 1,400 degree-days.

Hemlock seed began to mature by August 13, but showed little increase until the week of September 10, when germination percent surged sharply. Thereafter, more seed appeared to mature through October 16, the end of the sampling period, although again germination results were erratic. Hemlock seed began to mature when about 1,100 degree-days had accumulated, but the first substantial increase occurred after 1,300 degree-days and continued to increase until the season's total of 1,595 degree-days had accumulated.

Gross physical appearance of freshly collected cones and seed were noted during ripening (table 1). In the case of spruce, 48-percent germination was obtained from seed collected by August 20. At this time seedcoats were still cream colored and the "endosperm" (megagametophyte tissue plus integuments) soft. This was fully 6 weeks before seed took on the characteristic dark chocolate-brown color and endosperm assumed the firm consistency of maturity. Regression analysis showed that spruce cones increased in length only slightly during the collection period, from an average of 61.3 millimeters on July 30 to 66.5 millimeters on October 16.

Hemlock began to ripen abruptly 3 weeks later than spruce, the first substantial change occurring during the week preceding September 10, when average germination was 36 percent. At this time, seedcoats

^{2/} As defined here, one growing degree-day is accumulated for each 1° F. rise in temperature above a daily mean of 41° F. (5° C.). For example, if the daily mean is 51° F., 10 growing degrees would be accumulated for that day.

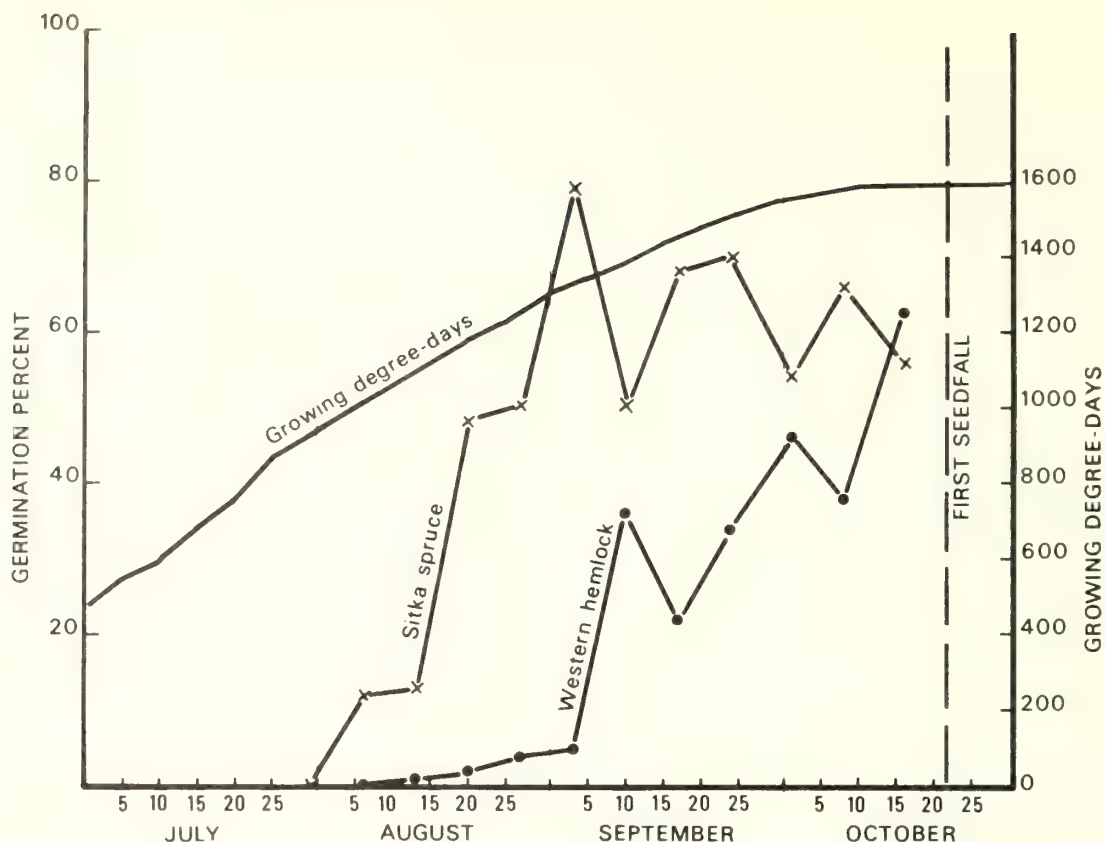


Figure 1.—Ripening of western hemlock and Sitka spruce seed collected at weekly intervals, Juneau, Alaska, 1966.

were cream colored, the wing still fragile and adhering to cone scales, and endosperm soft. Cones were tightly closed and still green. Seed did not take on the characteristic light-brown color and endosperm the firm consistency of maturity until October 8-16, only 2 weeks before seed began to fall. Hemlock cones increased in length only slightly, from an average of 16.8 mm. on July 30 to 18.0 mm. on October 16. Differences in seed ripening between trees is likely. However, samples were obtained from only one tree of each species, so no measure of variation was obtained.

Time of Seed Dispersal

In the case of both hemlock and spruce, a common observation is that cone scales open upon drying, thus releasing seed. This process was amply demonstrated. After cones matured, they opened in response to dry atmospheric conditions and reclosed in wet conditions (fig. 2).

Table 1.--Biological characters of western mountain pine tip species cones and seed during ripening, 1954, 1955, 1956

Collection date	Cumulative degree-days (base 41° F.)	WESTERN MOUNTAIN PINE					MOUNTAIN PINE				
		Germi- nation percent	Cone scale color	Seed wing color	Seed coat color	Seed contents	Germi- nation percent	Cone scale color	Seed wing color	Seed coat color	Seed contents
July 20	924										
August 6	1,014					Liquid, milky	12	Pale green; pale yellow			Soft; milky
August 13	1,094	1					1				Soft; milky
August 20	1,168		Green; pur- ple cone tip				48				
August 27	1,255	4			Pale green to cream, soft	Soft; not milky	50	Red purple		Gray white; firm	Pastelike
September 3	1,331			White; transparent; adheres to scale			79	Pale green to tan; purple tip		Light tan; crisp	Firm; crisp
September 10	1,378	16	Green; red- brown edge; purple cone tip	White to cream; adheres to scale	Pale green to cream, firm	Soft; pastelike	68	Purple red			
September 17	1,458	22									
September 24	1,502	34	Green to brown edge; brown cone tip	White to brown cone tip		Firm; pastelike	70	Light brown, dull purple purple tip	Purple	Light brown to dark brown, crisp	
October 1	1,556	46					54				Firm
October 8	1,587	58			Cream to tan, firm		66	Light brown; faded purple tip	Purple- brown	Dark choc- olate, hard	
October 16	1,595	63			Light brown to brown; firm	Firm			Purple brown to brown		

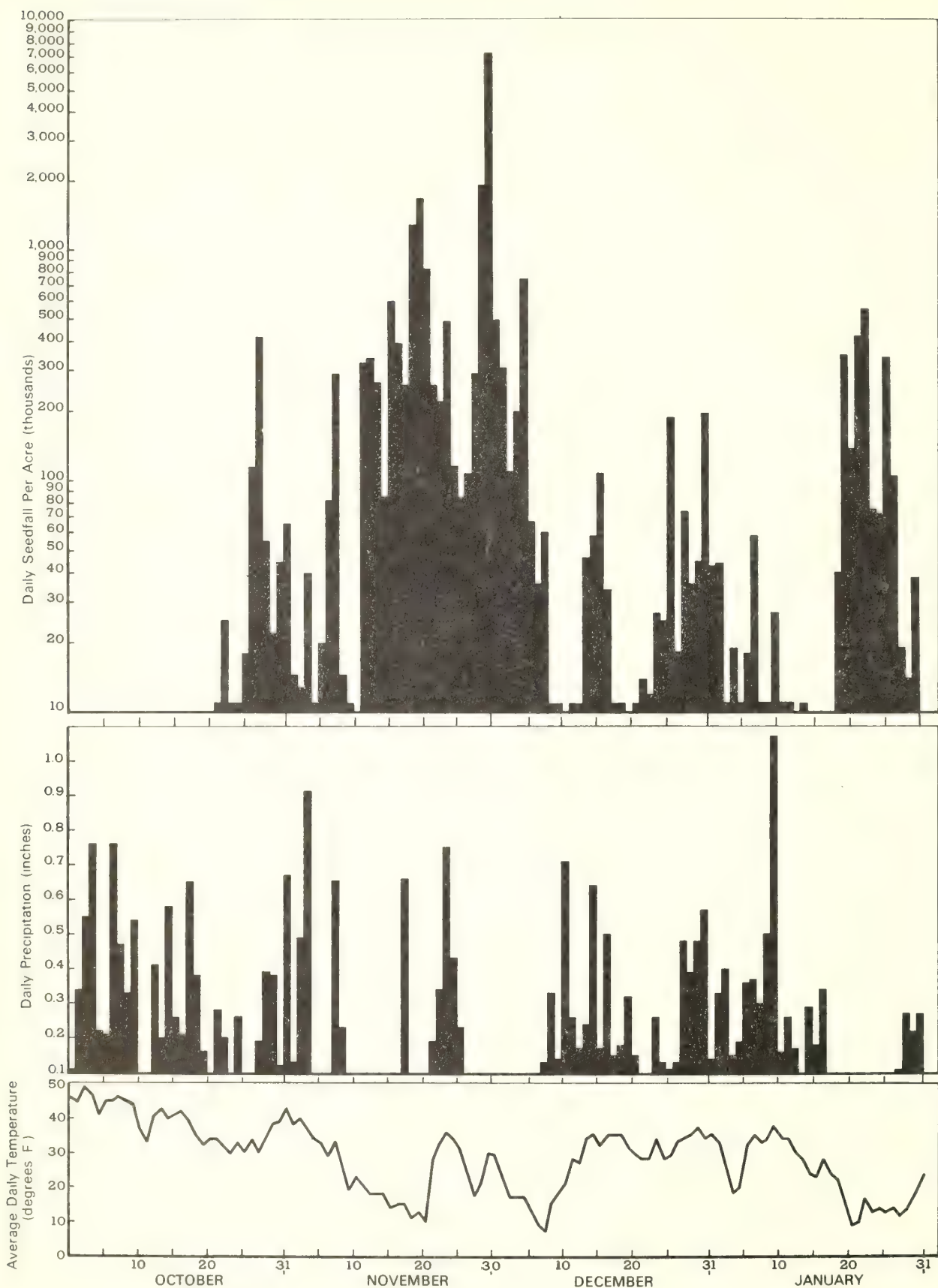


Figure 2.—Daily western hemlock and Sitka spruce seed dispersal, October through January 1966-67, Juneau, Alaska.

The first seeds fell on October 22, the second successive dry day following a week of rain. After this, seedfall was roughly correlated with dry weather and wind; that is, dry weather caused cone scales to open and wind helped to dislodge seeds. This process was evident from the number of seed falling daily. However, seedfall and precipitation as shown here do not correlate exactly because of several complicating factors:

1. Cones sometimes remained closed during days or part of days when no precipitation occurred, especially when cool, cloudy weather followed a period of heavy rain. Also, when dry, freezing weather immediately followed rain, saturated cones froze, and ice effectively held cones closed for a longer time than usual.
2. Because of the time lag in closing in response to moisture, cones often remained open for part of a day in which some precipitation fell. Such a change in weather pattern was usually accompanied by strong southeast winds.
3. During generally dry, freezing periods, a small amount of precipitation in the form of snow did not cause cones to close.

The general pattern of seedfall showed that cones opened during dry, windy weather. Cones opened and closed many times during the fall and winter, and many flexings of scales occurred before all seeds were dislodged.

Seed was dispersed over a 1-year period. During the 4 months (October-January) when seedfall was observed daily, at least 300,000 seeds (roughly 1 pound per acre) fell on 18 separate days. Greatest seedfall took place on November 30, when slightly over 7 million seeds (nearly 26 pounds) per acre fell. This seedfall, along with that which built up successively during 5 previous clear days, fell on crusted snow, and we received many reports of the tremendous number of seeds covering the snow. It was possible at this time to literally scoop up seed by the handful in depressions where it had been blown by the wind.

From October through January, most seed was dispersed when prevailing local winds were easterly (fig. 3). The largest percentage of seed (37 percent) was dispersed on days when the prevailing wind direction was from the southeast (110°). Next, 18 percent was dispersed when wind was from 80° , and 15 percent from 30° . During the fall and winter, dry weather in southeast Alaska is usually associated with general air movement from the interior located to the northeastward, and influenced greatly by local topography.

The bulk of spruce seed fell earlier than hemlock (fig. 4). By November 30, 73 percent of spruce seed had fallen compared with 45 percent of the hemlock seed. Both species retained some seed for over 1 year, the last dispersed in late October of 1967.

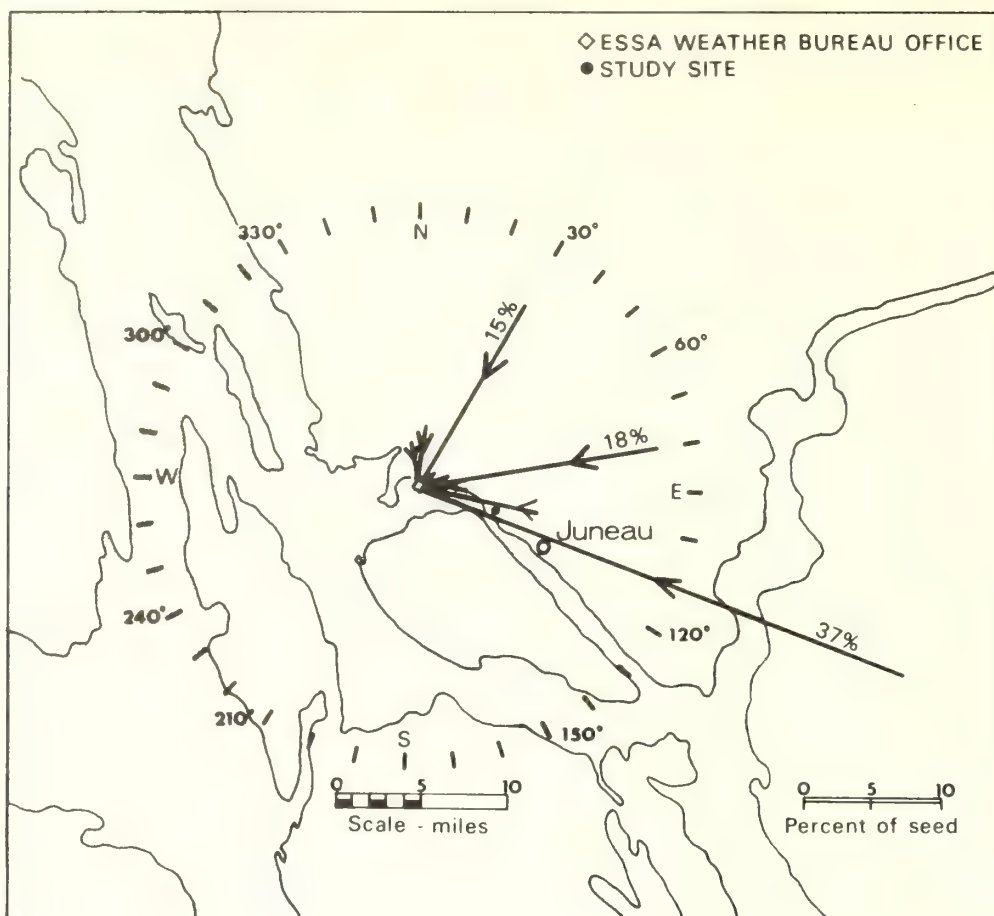


Figure 3.—Percentage of seed dispersed on days with prevailing wind direction indicated (length of vector line indicates percentage of seed dispersed). Juneau, Alaska, 1966-67.

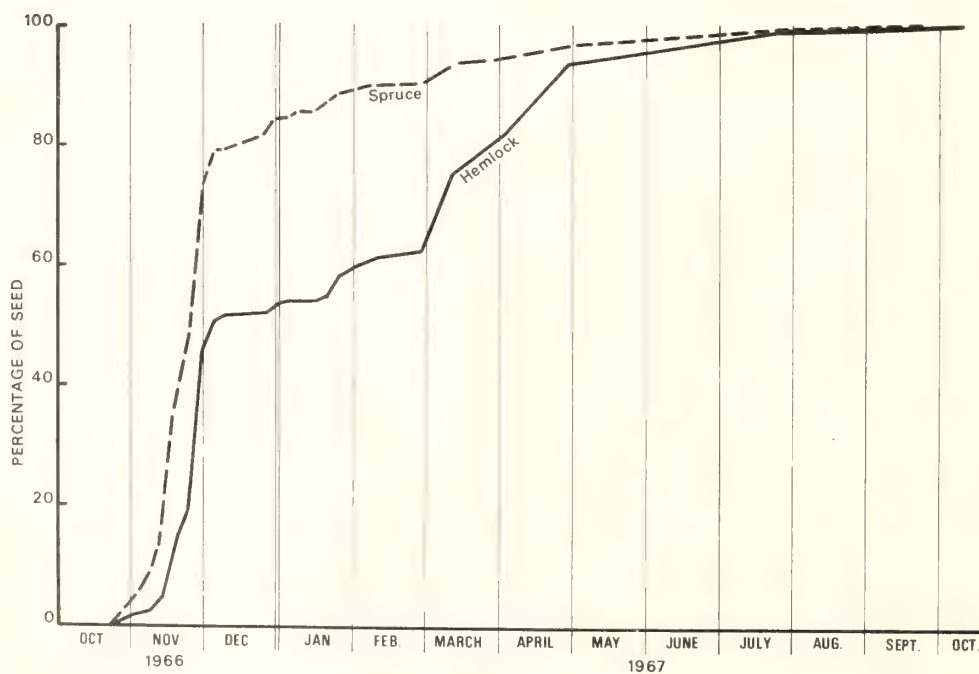


Figure 4.—Cumulative dispersal of western hemlock and Sitka spruce seed by date, Juneau, Alaska, 1966-67.

Total Seed Production

Total seed production of the stand averaged 37,195,000 seeds per acre, with the true average somewhere between 33,543,000 and 40,846,000 seeds per acre unless a 1-in-20 chance in sampling occurred. By weight this is equivalent to approximately 131 pounds per acre, the true average being between 118 and 144 pounds; 89 percent of this was western hemlock, 11 percent Sitka spruce.

Percentage of sound seed decreased during the period of dispersal (fig. 5). These percentages, applied to the amount of seed dispersed by date, indicated total sound seed produced by the stand averaged 20,380,635 hemlock and 2,742,465 spruce seed per acre, an average of approximately 82 pounds of sound seed per acre.

Seed soundness (fig. 5), as determined by cutting tests, suggested that the percentage of filled seeds remained fairly stable through January, then decreased, although test results were erratic. During the ripening period, seed soundness generally followed the pattern of germination test results but was consistently higher.

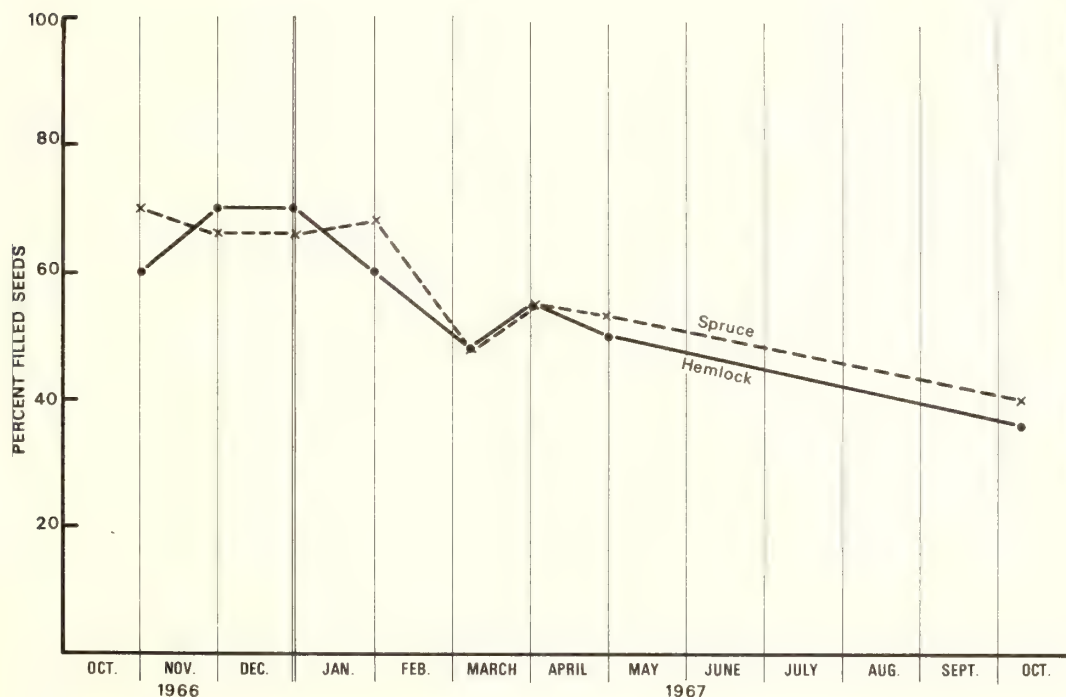


Figure 5.—Seed soundness by collection date, Juneau, Alaska, 1966-67.

CONCLUSIONS

Both hemlock and spruce are prolific seed producers. During the heavy seed year of 1966-67, a mature timber stand produced an average of 131 pounds of seed per acre. Soundness decreased with time of dispersal, averaging 63 percent sound by cutting test.

Sitka spruce seed ripened 2 to 3 weeks earlier than western hemlock. Seed of both species was mature enough to allow cone collecting by mid-September and immediate drying and seed extraction. Work with Douglas-fir has shown that seed continues to ripen in cones stored under cool, damp conditions (Silen 1958; Rediske 1961). If after-ripening occurs in hemlock and spruce, the cone collecting period may be similarly extended.

Seed color offered a conservative indication of maturity but failed to indicate clearly when seed first matured. Investigations by Sarvas (1967) in Finland have shown striking relationships between temperature sums and the course of annual physiological events of forest trees, especially with respect to anthesis. A method of temperature summation, such as that expressed by degree-days, may eventually offer an indication of when seed is mature, but much work will be needed before it is reliable. The temperature summation presented here is offered as a rough model only.

Once ripe, seed remained in closed cones on the trees until sufficiently dry weather occurred. Timing of seedfall depends on weather conditions, and each year may provide a different pattern. For example, in 1966, as reported here, the first seed fell on October 22. This is comparable to 1956, when James (1959) reported that no spruce and less than 2 percent of hemlock fell before October 25. This date is some 2 weeks later than the October 6 date reported for 1959 (Harris 1967) and a month later than the September 21-28 date reported for 1951 (Godman 1953).

Seed was released over a period of many months, with cone scales opening and closing in response to moisture and seedfall increased by wind. Many flexings of cone scales occurred before all seeds were dislodged.

Wind direction during dry weather, when cone scales open, was generally northerly or easterly and much seed was shed at these times. However, strong southeast winds often preceded autumn and winter storms, and seed was dispersed before cone scales closed in response to increased moisture content. Winds are strongly affected by mountains so that local topography must be considered when attempts are made to draw general conclusions about the direction of seed dispersal in southeast Alaska.

LITERATURE CITED

- Godman, R. M.
1953. Seed dispersal in southeast Alaska. U.S.D.A. Forest Serv. Alaska Forest Res. Center Tech. Note 16, 2 pp.
- Harris, A. S.
1967. Natural reforestation on a mile-square clearcut in southeast Alaska. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Res. Pap. PNW-52, 16 pp., illus.
- James, G. A.
1959. Seed production in a scrub stand. U.S.D.A. Forest Serv. Alaska Forest Res. Center Tech. Note 43, 3 pp.
- Rediske, J. H.
1961. Maturation of Douglas-fir seed--a biochemical study. Forest Sci. 7: 204-213.
- Sarvas, Risto.
1967. The annual period of development of forest trees. Finn. Acad. Sci. & Lett. Proc. 1965: 211-231.
- Silen, Roy R.
1958. Artificial ripening of Douglas-fir cones. J. Forest. 56: 410-413.
- U.S.D.A. Forest Service.
1948. Woody-plant seed manual. U.S. Dep. Agr. Misc. Pub. 654, 416 pp., illus.

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PNW-106

July 1969

SOME AUTECOLOGICAL CHARACTERISTICS OF ELK SEDGE

by G. O. Klock, *Soil Physicist*

ABSTRACT

Elk sedge (*Carex geyeri*), a grasslike plant with extensive fibrous root systems and apparent high drought tolerance, may be one of the most important native, herbaceous forage species on National Forest lands of Oregon and Washington. Quick establishment of elk sedge (*Carex geyeri*) on disturbed or depleted grazing lands of Oregon and Washington would be desirable for erosion control. However, reproduction from seeds in the laboratory has not yet been successfully accomplished. "Cores" were transplanted to the laboratory to investigate this method of reproduction and to provide material for tests of this plant's response to fertilization. The transplanting practice was successful and elk sedge showed positive response to nitrogen and potassium fertilization.

INTRODUCTION

In a number of areas on the eastern slopes of the Oregon and Washington Cascade Range, extremely erosive conditions have developed. In many of these watersheds, the terrain is quite steep and erodibility is highly influenced by the amount and type of vegetative cover.

Pinegrass (*Calamagrostis rubescens*), lupine (*Lupinus* spp.) and elk sedge (*Carex geyeri*) are the dominant ground cover on the watersheds.^{1/} Apparently, elk sedge will tolerate unfavorable conditions, such as high soil temperatures and high soil moisture stress, as well as produce a

^{1/} Rummel, R. S. Some effects of livestock grazing on ponderosa pine forest and ranges in central Washington. Ecology 32: 594-607. 1951.

dense, extensive root system which is desirable for stabilizing soils on sites actively eroding or potentially erodible.

Little information is available on the autecological characteristics of elk sedge. Since it appears desirable to extend the distribution of elk sedge on depleted sites, we need more knowledge of some of these characteristics.

METHODS

Little is known about propagating elk sedge. The plant normally produces one seed per spike annually which is available for harvest for only a few days. For this reason, there is a very limited supply of seed. Also, Wiesner et al.^{2/} have shown that the potential seed viability of a number of sedge species is low; therefore, high germination percentages could not be expected. With 2 years of effort, Kirk^{3/} has been unable to germinate seed collected in the Wenatchee, Wash., area.

For this reason, "plugs" 2 inches in diameter normal to the ground surface were taken in March from an apparently healthy, vigorous elk sedge clone growing in the Mission Creek watershed. In the laboratory, collected cores were sorted, tops removed, graded to a uniform size, and planted in individual plastic pots. A resident soil from the Mission Creek watershed was used for potting material. Physical and chemical analyses of this soil are listed below:

Sand: 74.1 percent

Silt: 15.9 percent

Clay: 10.0 percent

Cation exchange capacity: 17.29 meq. per 100 g.

Organic matter: 1.61 percent

Element analysis:

N	0.03 percent (total)	Na	0.20 meq. per 100 g.
P	11.0 p.p.m.	Mn	0.01 meq. per 100 g.
K	0.53 meq. per 100 g.	Al	0.14 meq. per 100 g.
Ca	10.88 meq. per 100 g.	Zn	0.01 meq. per 100 g.
Mg	1.49 meq. per 100 g.	Fe	0.01 meq. per 100 g.

^{2/} Wiesner, L. E., Carleton, A. E., and Bailey, R. C. Seed evaluation of sedge species. Mont. Agr. Exp. Sta. J. 831, 9 pp., illus. 1967.

^{3/} Kirk, J. Personal communication. Forest Hydrology Laboratory, Pacific Northwest Forest & Range Exp. Sta., Wenatchee, Wash. 1968.

The individual pots were irrigated to near field capacity each time the soil moisture stress approached two bars. A soil moisture release curve is shown in figure 1. The pots were placed in an open area exposed to full sunlight.

At the time of transplanting, 12 fertility levels were imposed to provide an estimate of the plant's nutrient level requirements. A split-plot design was used with four replications. Treatment levels used were: nitrogen, 0, 100, and 200 pounds per acre; phosphorus, 0 and 200 pounds per acre; and potassium, 0 and 200 pounds per acre. Chemical fertilizers used were ammonium nitrate (NH_4NO_3), super phosphate (P_2O_5), and muriate of potash (KCl).

After 120 days of growth, the vegetation of all treatments was clipped at a height of 3 centimeters above the soil surface for a measurement of forage production. After an additional 60 days of growth, a second cutting was made.

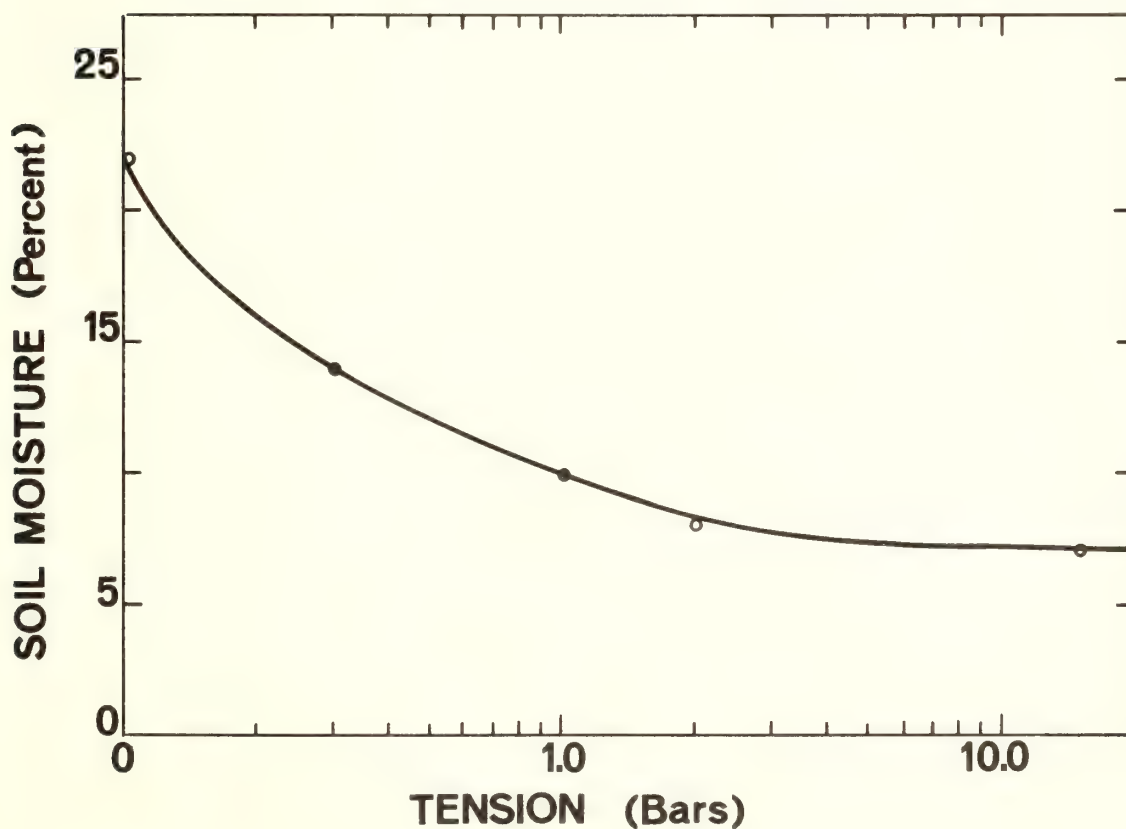


Figure 1.--*Soil moisture-tension relationship for the resident soil used for potting elk sedge.*

RESULTS

The ovendry vegetation yields in grams per pot for the first and second cuttings are shown in table 1. The figures in table 1, multiplied by 555, place this yield on a per-acre basis of pure stand. The first cutting showed a significant response (1-percent significance level) for both nitrogen and potassium, with the nitrogen having the predominant treatment influence on yield. The heavy application of phosphorus to a soil already containing 11 parts per million (p.p.m.) may have contributed to the negative response for this element.

Table 1.--*Yield of elk sedge in response to three levels of nitrogen, two levels of phosphorus, and two levels of potassium fertilizer application*
(In grams^{1/} per pot)

Nutrient	Level of application (pounds per acre)	Nitrogen (pounds per acre)			
		0	100	200	Mean
FIRST CUTTING ^{2/}					
Phosphorus (P ₂ O ₅)	0	1.00	1.47	3.03	1.83
	200	1.31	1.86	1.91	1.69
Potassium (K ₂ O)	0	1.09	1.31	2.23	1.54
	200	1.23	2.01	2.71	1.98
	Mean	1.15	1.67	2.47	1.76
SECOND CUTTING ^{3/}					
Phosphorus (P ₂ O ₅)	0	.77	1.35	1.47	1.20
	200	.85	.85	1.07	.92
Potassium (K ₂ O)	0	.67	1.15	1.57	1.13
	200	.95	1.05	.97	.99
	Mean	.81	1.10	1.27	1.06

^{1/} Ovendry weights.

^{2/} 120 days of growth after transplanting.

^{3/} 60 days of growth after first cutting.

Only a nitrogen treatment response was evident in the second cutting. This cutting was influenced to an unknown degree by the potting conditions. Frequent pot watering was necessary due to high summer temperatures, and some leaching may have occurred. Although all core plantings showed new growth, five out of the 48 plants used in the experiment died from unknown causes. The roots of the surviving plants fully permeated the pot.

CONCLUSIONS

It can be concluded that elk sedge (*Carex geyeri*) will withstand coring, transplanting, and greenhouse cultivation techniques. The species continued to respond to nitrogen and potassium fertilization up to the top treatment level of 200 pounds per acre. Although the root development was excellent, which is very important for erosion control, the annual forage yield in the experimental pots was not exceptional.

The planting technique employed in this study is being tested under field conditions to confirm the laboratory results.

PNW-107

July 1969

FLUORESCENT MATERIALS INDEX SOIL MOVEMENTS

by

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and

H. W. Berndt, *Principal Research Forester*



ABSTRACT

Tracing movement and dispersion of soil-sized fluorescent particles is a promising method for detecting and describing soil erosion. Actively eroding and stable sites are readily identified; size of particles in motion and causal agents may also be inferred. Equipment is simple to operate, and no health hazards are involved.

There is a need for easy-to-use methods of recognizing or identifying active erosion, determining its cause, and appraising relative erosion rates in mountain watersheds. Such information should be available for use in prescribing and evaluating corrective treatments for actively eroding areas or selecting management options on potentially erodible areas. Furthermore, decisions as to whether or not erosion is taking place at an accelerated rate require methods that can be applied to adjacent disturbed and undisturbed areas for comparison.

Because of the variability in both soils and local climate, erosion appears differently at different places. Evidence such as muddy streams, mudflows, dry gravel cones, topographic slumping, or other mass soil movements are clearly recognizable effects of erosion; and several qualitative indicators are commonly used to detect erosion occurrence. These include study of visible factors on the ground

surface as well as study of streambed characteristics (Gleason 1953). Certain physical measurements to quantify sediment loss from hydrologic units include use of gully transects and other aids to estimate soil loss per unit area (Gleason 1957), measurement of bedload sediment volume deposited at a settling point or debris basin (Leaf 1966), and determination of weight of suspended sediment per unit volume of streamflow (Inter-Agency Committee on Water Resources 1963). These methods are useful in determining volumes of materials transported from a land unit, but they provide no insight as to sediment sources. Nor do they indicate patterns of soil movement on eroding surfaces.

Recognition of less obvious or insidious detachment and transport of smaller particles requires closer and more careful observation. Interpreting this degree of soil movement generally requires some identification of the soil material for repeated reference. Advances in detection of tagged materials using short-lived radionuclides have provided a sensitive method for detection of soil particle movement (Wooldridge 1965). However, the ability to detect radionuclides attached to soil materials is reduced with time due to onsite dispersion and radioactive decay. Equipment requirements, radioactive hazards, and reproducibility are particular disadvantages.

Fluorometric particle identification also provides a means of following materials in transit. In general, this entails the introduction of detectable artificial particles into a natural environment. The introduced material is chosen to closely resemble and reproduce the transport characteristics of natural particles. Detection of fluorescent compounds can approach or exceed that of radioactive materials in sensitivity, and the method has been successfully applied to studies of atmospheric diffusion of aerosols (Stanford University 1955). Fluorescent-coated natural particles have also been used to analyze sediment transport along rivers and beaches (Yasso 1962). More recently, Young and Holt (1968) reported use of a specially prepared fluorescent glass to trace soil movement on cultivated experimental plots.

In this preliminary study, natural ore (sp. gr. 3.83) containing fluorescent willemite (zinc silicate with a manganese activator) was used as a tracer. This material has a spectacular yellowish-green response to ultraviolet light (2,500 Angstrom units) emitted by inexpensive mineral-prospecting lamps commonly in use. Prior to application, the willemite ore was crushed and graded to sizes equivalent to soil fractions.

Six plots representing a range of erosion activity from high on bare sites to expected stability in a timber type with herbaceous understory were selected for study. Soils on all plots were gravelly loams derived from basalt, with easterly exposures on 12- to 15-percent slopes. In October 1967, referenced bands of sand- (0.2-2.0 mm.),

gravel- (2.0-5.0 mm.), and stone-sized fluorescent particles were established on the soil surface of each plot. Patterns established on three plots are illustrated by figures 1A, 2A, and 3A.^{1/}

Reexamination of the plots in September 1968 showed that evidence and relative rates of erosion can be detected by this method (figs. 1B, 2B, and 3B). As anticipated, the smallest sized material was the most sensitive indicator of erosion activity. During the period of study, this material was displaced a maximum of 6 inches from the reference band on the stable plot (fig. 1), 5 feet under the median condition represented by figure 2, and as far as 15 feet on the most actively eroding plot (fig. 3). Movement and burial of the larger sized particles was also apparent on the actively eroding plots, in contrast to their incorporation into litter accumulating on the stable plot.

No estimate of the relative importance of agents responsible for particle transport was possible in this study. Wind and water erosion moved material in the same general direction at these plot locations. However, some uphill movement of the smaller particles can be seen in figure 2B. We feel that surface water released by snowmelt when protective cover was dormant was the major cause of movement. By periodically reexamining sites at more frequent intervals than the 1-year period in this study, one could trace the progress of total particle movement through different seasons. From this information, inference as to the relative contributions of different erosion-causing forces would be possible.

^{1/} Photographs are used as aids in describing the method but are not normally required for field analysis.



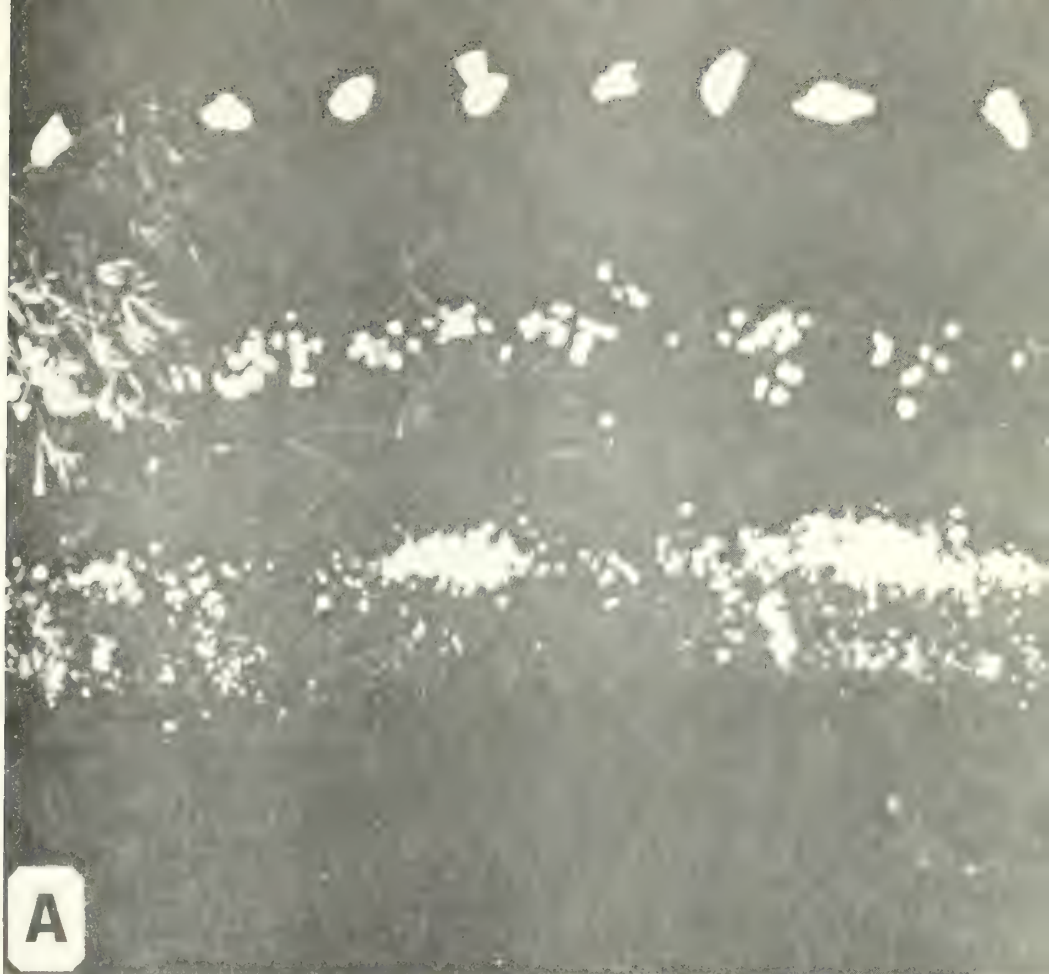
A, Bands of fluorescing minerals established in October 1967 on stable plot.



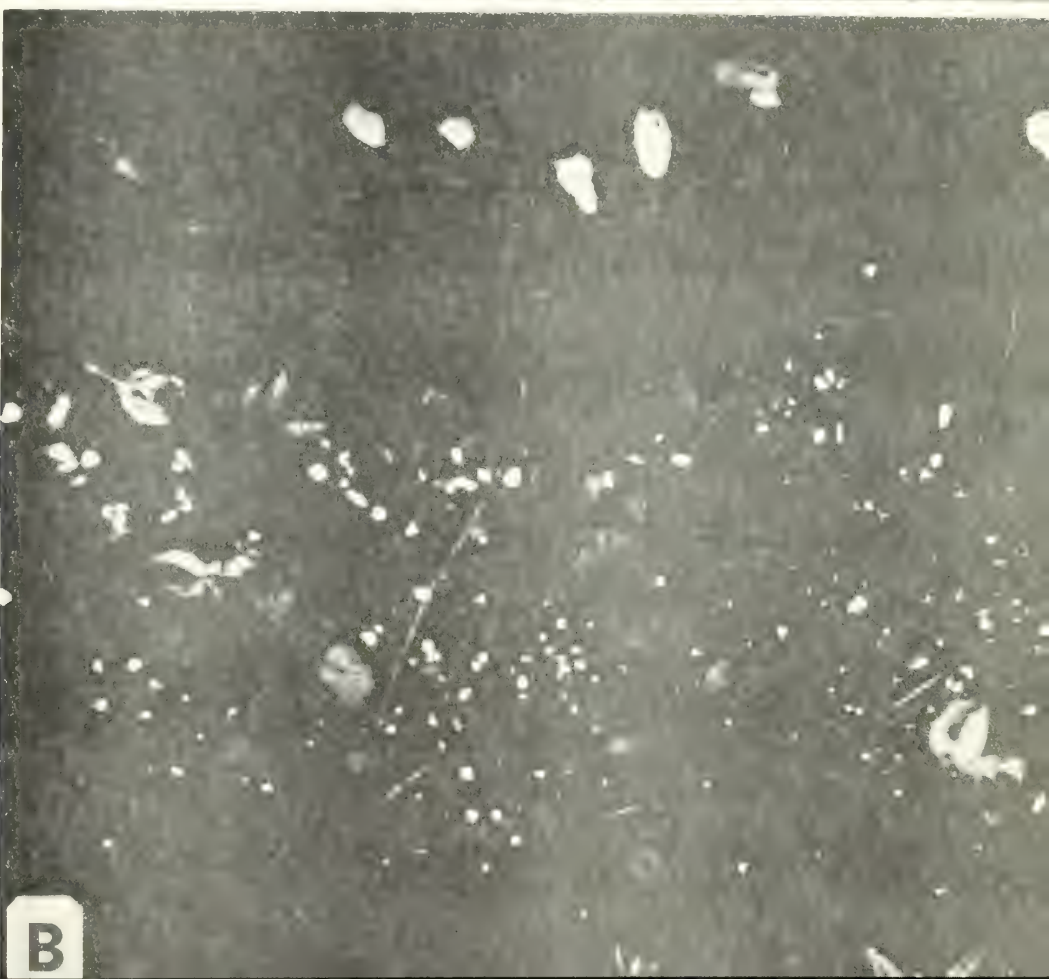
B, Same plot in September 1968. Approximate location and distance between large particles maintained during enlargement.

Figure 2.--

October 1967. Similar
s on plot of median
ility.



September 1968. Location
ands on median condition



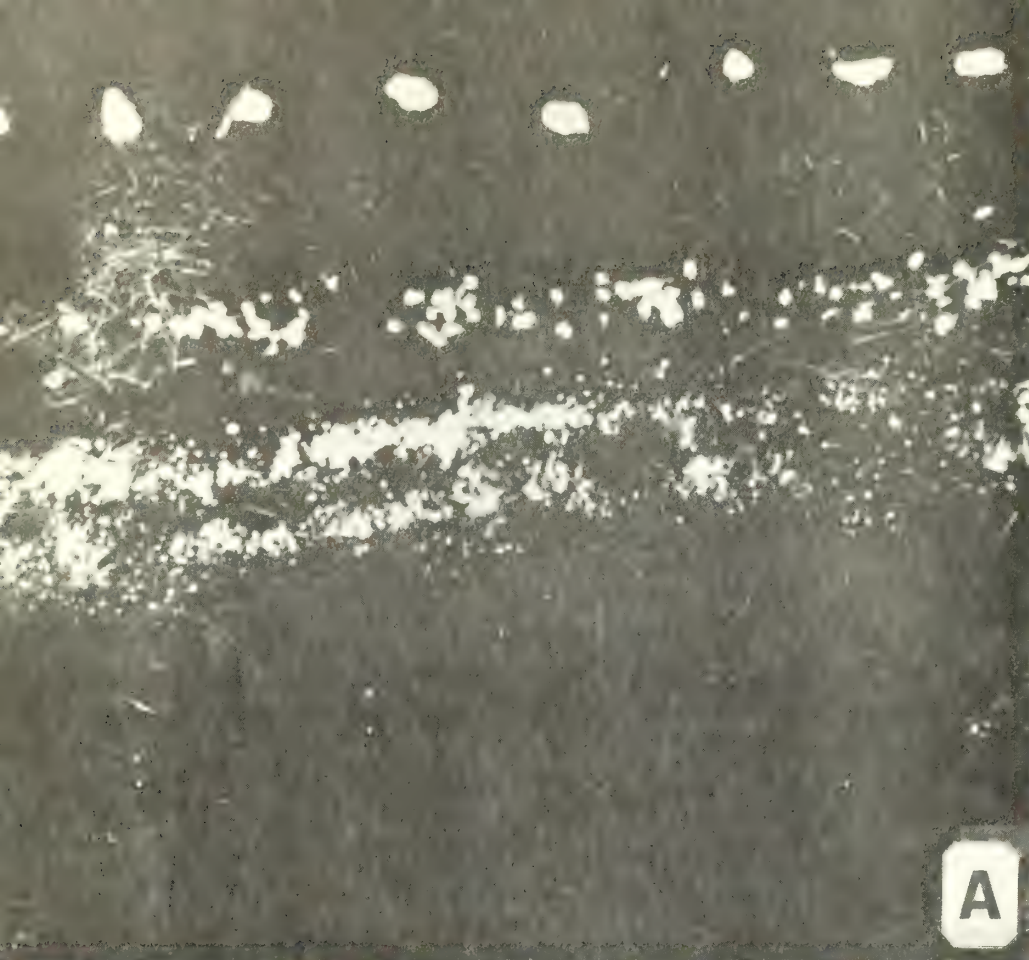


Figure 3.--

A, Bands of minerals on 1 of suspected high erosion rates, October 1967.



B, Remaining isolated mineral particles on this most active plot, September 1968.

LITERATURE CITED

Gleason, Clark H.

1953. Indicators of erosion on watershed land in California.
Amer. Geophys. Union Trans. 34: 419-426.

Gleason, Clark H.

1957. Reconnaissance methods of measuring erosion. J. Soil &
Water Conserv. 12: 105-107.

Inter-Agency Committee on Water Resources.

1963. Measurement and analysis of sediment loads in streams.
Subcomm. Sedimentation, Rep. 14, 151 pp., illus.

Leaf, Charles F.

1966. Sediment yields from high mountain watersheds, central
Colorado. Rocky Mountain Forest & Range Exp. Sta.
U.S.D.A. Forest Serv. Res. Pap. RM-23, 15 pp., illus.

Stanford University.

1955. The Stanford fluorescent-particle tracer technique. Dep.
Chem. Reproduced by the Armed Services Tech. Inform.
Agency, Rep. AD 91194, 153 pp., illus.

Wooldridge, David D.

1965. Tracing soil particle movement with Fe-59. Soil Sci. Soc.
Amer. Proc. 29: 469-472.

Yasso, Warren E.

1962. Fluorescent coatings on coarse sediments: an integrated
system. Office Naval Res., Geogr. Br., Tech. Rep. 1,
48 pp., illus.

Young, R. A., and Holt, R. F.

1968. Tracing soil movement with fluorescent glass particles.
Soil Sci. Soc. Amer. Proc. 32: 600-602.

PNW-108

July 1969

A SIMPLE, QUANTITATIVE METHOD OF ASSAYING SOIL
FOR INHIBITORY FUNGI^{1/}

by

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ABSTRACT

*Micro-organisms isolated from soil can be easily tested for inhibition of root pathogens such as **Poria weirii**. The isolates are transferred by toothpick probes to the surface of a double-layered agar plate containing pathogen mycelium sandwiched between the agar layers. The pathogen does not grow under inhibitory organisms.*

Assaying soil for content of micro-organisms that produce antibiotics against a specific fungus has usually involved (1) isolation of the micro-organisms from a soil dilution plate, (2) individual cultivation of isolants in a suitable medium, and (3) testing of each isolant against the fungus in question. This method is laborious and time consuming.

^{1/} Text is derived from "A simple, quantitative method of assaying soil for inhibitory fungi" by the same authors, published in *Soil Biology--Int. News Bull.* No. 10, pp. 6-7, 1969. The information is being reissued in this note so that it will be available to a wider audience and illustration can be included. This study was supported in part by U.S. National Science Foundation Grant No. GB-3214.

^{2/} Oregon State University.

More efficient methods have been developed for tests against fungi that sporulate in culture.^{3/} The soil dilution plates are sprayed with spore suspensions; inhibition zones around soil micro-organisms growing on the plate are then detected in the otherwise evenly distributed mycelium that develops from the spores.

Because this last method is not usable for the many fungi which do not sporulate in culture, Koike^{4/} devised an alternative. Water-agar plates of the test fungus are covered with a thin layer of potato dextrose agar (PDA). Entire agar disks of soil dilution plates are then inverted on top of the fungal plates. As the test fungus develops into the PDA, inhibition zones can be detected. This method entails the minor inconvenience of requiring two sizes of petri dishes. More importantly, our trials of it with *Poria weirii*, an important pathogen of conifer roots in western North America, produced erratic results. Particularly bothersome was the lack of control over spacing of the soil micro-organisms on the dilution plates. Often, two or more colonies overlapped or were so close that it was difficult to decide which produced an antibiotic action. Moreover, neither this nor the other methods mentioned permit easy replication. Consequently, a new, simple method was devised to overcome these deficiencies for our studies with *P. weirii*.

The Method

Serial dilutions of soil are prepared in sterile distilled water, starting with 20 grams of soil (ovendry basis) in 100 milliliters of water. The dilutions are carried out to 1:5,000 for fungi and 1:50,000 or 1:500,000 for *Streptomyces* spp. and bacteria. Aliquots of 1.0 milliliter of the respective final dilutions are plated out on Martin's peptone-dextrose rose bengal agar, containing 30 parts per million of streptomycin sulfate for fungi, or on sodium albuminate agar for *Streptomyces* spp. and bacteria.

^{3/} Stansly, P. G. A bacterial spray apparatus useful in searching for antibiotic-producing microorganisms. J. Bacteriol. 54: 443-445. 1947.

Stessel, G. J., Leben, Curt, and Keitt, G. W. Screening tests designed to discover antibiotics suitable for plant disease control. Mycologia 45: 325-334. 1953.

Tsao, Peter H., Leben, Curt, and Keitt, G. W. An enrichment method for isolating actinomycetes that produce diffusible antifungal antibiotics. Phytopathology 50: 88-89. 1960.

^{4/} Koike, H. An agar-layer method useful in detecting antibiotic-producing microorganisms against *Phythium graminicola*. Plant Dis. Rep. 51: 333-335. 1967.

Mycelium of *P. weirii*, grown in shake culture, is harvested, washed twice, and homogenized in a Waring blender. Two milliliters of the mycelial suspension are plated on 2 percent water agar, then covered with 5 milliliters of melted malt agar.

Colonies on soil dilution plates are transferred to the *P. weirii* plates as evenly spaced, point inoculations by sterile, sharp-tipped, birch toothpicks. A colony is probed with a toothpick, whose tip is then poked into the selected point on the test plate. The toothpick is then discarded. Invariably effective transfer was achieved by this method.

Trial runs, with a grid of about 15 millimeters between point inoculations, were satisfactory. A set of colonies can be replicated on as many plates as desired, either in a fixed sequence or randomized. Location of each colony of a set can be conveniently recorded by number for each replicate on diagrams of the grid.

The malt agar permits *P. weirii* to grow as a thick mycelial mat in which inhibition zones around colonies of the soil micro-organisms show distinctly (fig. 1). Size of inhibition zones indicates the relative degree of antagonism. The number of antagonists per gram of soil can be calculated by multiplication of the average number per plate (or plates, if more than one is needed to include all colonies from a given dilution plate) by the appropriate dilution factor.

This simple procedure combines rapid detection of microbial antagonists in soil with good control of colony spacing, increased accuracy of determination, and ease of replication. Although we have used it thus far only with *P. weirii*, it presumably would work effectively with other fungi, sporulators and nonsporulators, as well.

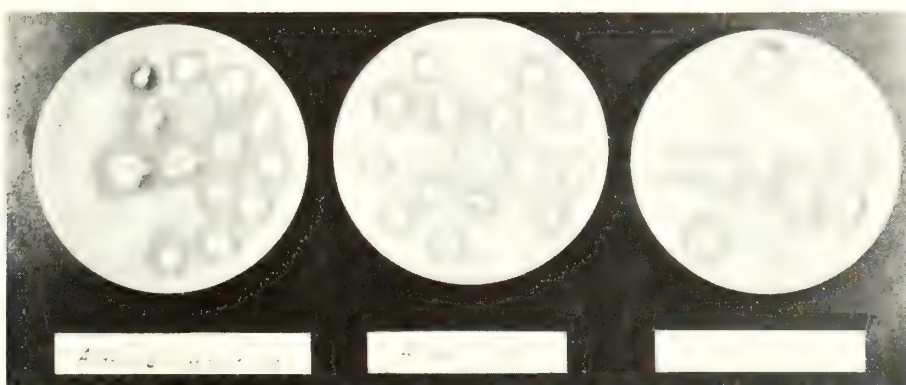


Figure 1.--Assay plates for inhibition of *Poria weirii* by randomly selected isolates of soil microfungi from a mixed conifer-alder stand (left), a pure alder stand (center), and a pure conifer stand (right) *Poria* grows uniformly on the agar surface except for clear zones around colonies of inhibitory microfungi.

August 1969

by

ABSTRACT

INTRODUCTION

^{1/} Fahrenheit is used throughout this report.

^{2/} U.S. Forest Service. National Fire-Danger Rating System handbook, 5100-26 (rev. 2/64).

In review, the initial stage of development of the NFDRS was the spread phase. A basic spread index provides ratings of the relative rate of spread for either fine or intermediate fuels. Figure 1 shows diagrammatically the spread phase and its components. As can clearly be seen, fine-fuel moisture is really the key component. This element was normally obtained by use of either dry bulb temperature and relative humidity or dry bulb temperature and wet bulb depression.

The tables, as presented in this paper, have been adopted by the Bureau of Land Management for use throughout the interior of Alaska. These same tables have also been used in development of danger-rating information from historical weather records on which only dry bulb temperatures and dewpoint temperatures were available. Computer programs have also been adapted to utilize the fuel moisture tables outlined.

PROBLEM

Two closely related local problems prompted the development of an additional set of tables to supplement those already available. In one case, a historical record for Alaska on the broadest data base possible was needed for research and development purposes. The second problem involved the day-to-day requirements of protection agencies using the NFDRS in Alaska. Many of the weather records for Alaska have only dry bulb and dewpoint temperatures on them. Over 50 percent of the fire-danger station network observations in Alaska are obtained from the Federal Aviation Administration and Weather Bureau teletype network stations which provide only dry bulb and dewpoint temperatures. Essentially then, data for Alaska--both of a historical nature and for daily operational use--was not available in a readily usable form. Therefore, if fine-fuel moisture tables could be developed which would use the existing weather data, many of our problems would be eliminated.

TABLES

A formula developed by J. J. Keetch and George Byram,^{3/} which indicates the relationship of dry bulb temperature and dewpoint temperature to fine-fuel moisture, was the basis for the tables. The formula is as follows:

$$\text{Log}_e M = 3.849244 - 0.032019\text{DB} + 0.018703\text{DP} - 0.173610\text{Log}_e (\text{DB} - \text{DP})$$

where M=fine-fuel moisture (in percent)
 DB=dry bulb temperature (degrees F.)
 DP=dewpoint temperature (degrees F.)

^{3/} U.S.D.A. Forest Service. Derivation of spread phase tables, National Fire-Danger Rating System, Division of Fire Control, Washington, D.C. 1966.

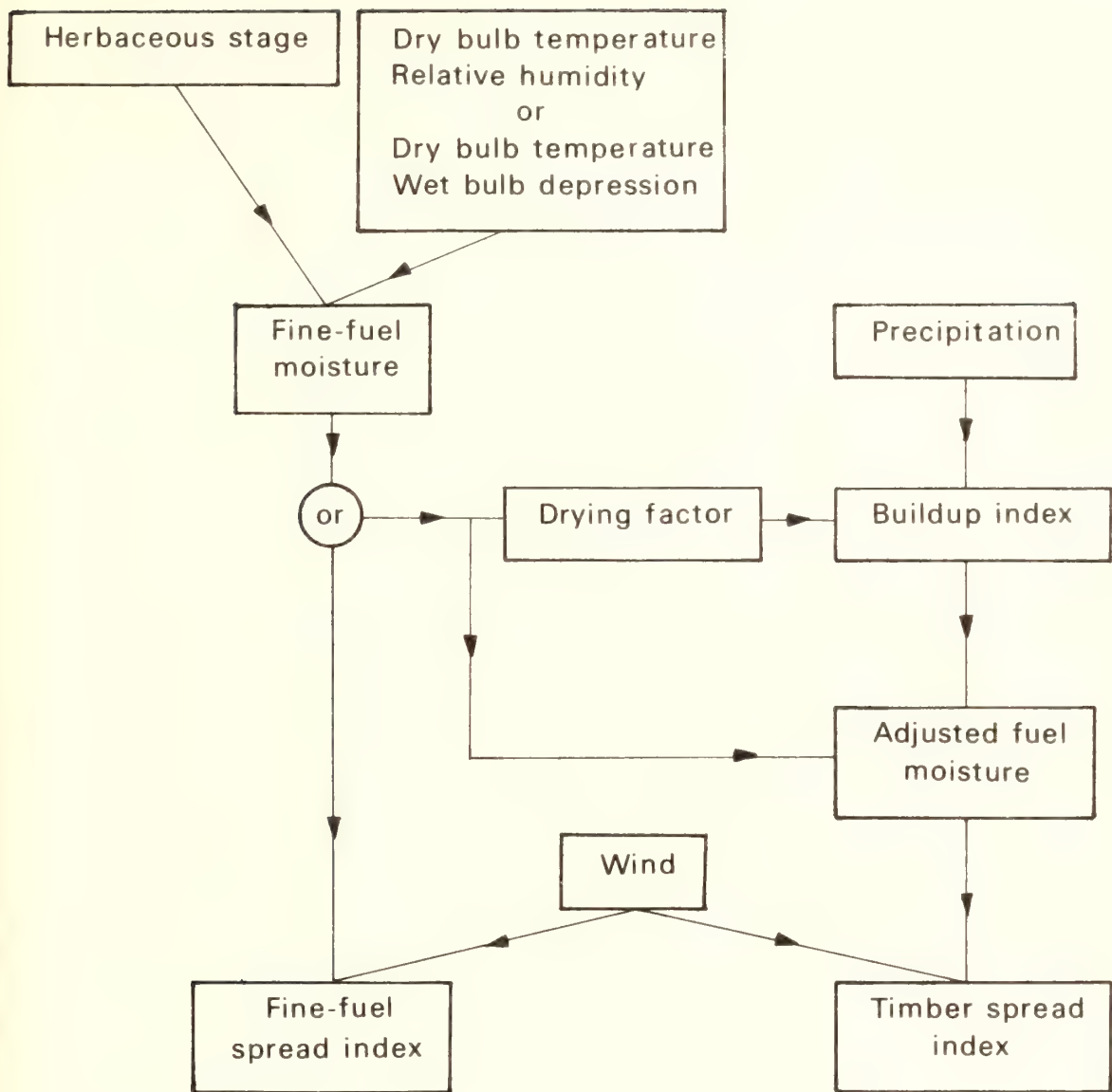


Figure 1.--Components of the spread phase, National Fire-Danger Rating System.

Several tables were developed, in which dry bulb temperature and dewpoint temperature were used as the entry data.^{4/} The final table decided upon in the developmental phase had convenient temperature ranges to work with. Values in the table are the result of the above formula and midpoint value of the appropriate dry bulb and dewpoint temperature range (e.g., 80-84 would be represented by a midpoint value of 82, etc.). For the purpose of development and analysis, only the table for the cured herbaceous stage was considered (table 4, "Appendix"). Tables for three stages of vegetative maturation--green, transition, and cured--are given in the appendix.

COMPARISONS

The NFDRS tables used in Alaska are the version using dry bulb temperature and wet bulb depression (footnote 2). These tables and the resulting fuel moistures and danger indexes were considered as the standard. Fuel moistures and danger indexes were calculated by use of the new fuel moisture tables, but the same weather data were compared with the standard.

Fine-fuel moistures, spread indexes, and buildup indexes were calculated from data from two weather stations--Fort Yukon (2 years) and Big Delta (3 years)--by use of both the standard and the new table. These data covered easy, average, and severe fire seasons. The resulting values provided 915 data points for comparison and evaluation checks.

Fuel-moisture contents.--In a check of midpoint values of the new table for each of its 300 cells, 257 cells agree within ± 0.5 percent moisture content with the standard table values. The majority of the larger differences occur below a dry bulb temperature of 32°F. where the moisture contents run too high. Other differences occur above the dewpoint range of 50°-59° F. where each indicated moisture content immediately above each of the 30+ values is too low.

Although differences of fuel moisture values obtained by the new tables do occur, many of them have a tendency to become minimized or lost in subsequent index calculation steps. The reason for this is that portions of tables, using fine-fuel moisture content as one of the entry data, use it in the form of ranges. For example, in a calculation of adjusted fuel moisture values, fine-fuel moisture content values of 9.5 through 11 would result in the same answer because of the table characteristics. This same situation exists in the spread index table calculations above a fuel moisture value of 10.

^{4/} Barney, Richard J. Development of fine-fuel moisture tables for the National Fire-Danger Rating System in Alaska. 1967. (Unpublished report on file at the Institute of Northern Forestry, Juneau, Alaska.)

When the table is made relatively compact and 5° temperature ranges are used, some of the sensitivity and, therefore, accuracy is lost. However, a table using single degrees of dry bulb and dewpoint temperature would be cumbersome. A compromise of table size maintained an acceptable level of accuracy. Since dry bulb temperature ranges are used in the standard tables, this procedure was continued.

Spread and buildup indexes.--As was mentioned earlier, danger-rating indexes were calculated on the basis of both the standard and the new fuel moisture tables. Values for individual days were compared by subtraction of the index based on standard tables from the index based on the new tables, resulting in plus, minus, or zero differences. Table 1 lists the differences encountered in both spread-index and buildup-index values. A negative difference indicates that the index calculated on the basis of the new tables was less or lower than the standard table version and a positive difference indicates it was greater or a higher value.

As shown in table 1, the indexes calculated on the basis of the new fine-fuel moisture tables tended to be somewhat lower than those calculated from the standard tables. However, 84 percent of both index values were within ± 5 index points of the standard, and 93 percent were within ± 9 index points for the 915 days compared.

A tabulation of differences by spread-index ranges (table 2) shows that the magnitude of the difference generally decreases as the spread index increases. The very high difference of minus 30 in the 0-9 spread-index range occurred at temperatures well below freezing and is of little practical importance. Many of the other relatively large variations occurred when new fine-fuel moisture content values resulted in entry of the spread index tables one or two rows above or below the point of entry of standard fine-fuel moisture content values under the same weather conditions.

A similar tabulation for buildup-index ranges (table 3) shows that the difference increases as the buildup index increases up to a point, then tapers off. Since the buildup is a cumulative index, such a situation is to be expected. Any difference encountered is normally 10 percent or less when compared to the standard version of the index values. The maximum difference was a -14 occurring in the 80-99 buildup-index range.

SUMMARY

Fine-fuel moisture tables have been constructed with 20 ranges of dry bulb temperature and 21 ranges of dewpoint temperature of 5° F. each. The ranges break at convenient points for easy use and are limited enough in size and number to allow for a relatively compact table. In the use of these tables, calculation will automatically be

Table 1.--*Distribution of spread- and buildup-index differences
based on new and standard fuel moisture tables*

Difference ^{1/}	Spread index		Buildup index	
	Number of cases	Percent	Number of cases	Percent
-10 and greater	8	0.9	40	4.4
-9	2	.2	12	1.3
-8	7	.8	9	1.0
-7	9	1.0	8	.9
-6	7	.8	20	2.2
-5	30	3.3	31	3.4
-4	61	6.7	79	8.6
-3	73	8.0	65	7.1
-2	141	15.4	76	8.3
-1	114	12.5	109	11.9
-0	220	24.0	299	32.7
+1	37	4.0	50	5.4
+2	50	5.5	11	1.2
+3	52	5.7	14	1.5
+4	37	4.0	18	2.0
+5	15	1.6	18	2.0
+6	20	2.2	16	1.7
+7	8	.9	7	.8
+8	4	.4	7	.8
+9	5	.5	5	.5
+10 and greater	15	1.6	21	2.3
Total	915	100.0	915	100.0

^{1/} A negative difference indicates that the index calculated on the basis of the new tables was less or lower than the standard table version and a positive difference indicates it was greater or a higher value.

Table 2.--*Differences in spread-index values based on new and standard fuel moisture tables, by index ranges*

Spread-index range	Maximum plus difference	Maximum minus difference	Average difference	Number of cases
0-9	6	-30	-3.0	68
10-19	16	-8	.7	227
20-29	16	-9	.2	271
30-39	13	-7	-.2	178
40-49	16	-7	-.8	86
50-59	9	-8	-1.4	49
60-69	2	-7	-2.5	25
70-79	3	-7	-1.5	8
80-89	3	-10	-3.5	2
90-99	--	-6	-6.0	1

Note: Difference equals index value calculated with new fuel moisture tables minus index value calculated with standard fuel moisture tables.

adjusted for elevational differences since dewpoint temperatures are determined in such a manner as to account for differences in pressure or elevation.

Although differences have resulted in indexes based on the standard fine-fuel moisture table and new fine-fuel moisture table version of calculations, they appear to be well within acceptable limits for use in Alaska. We have more variation in the country and weather between our widely scattered fire-danger stations than occurs in the tables and resultant indexes. Also, we are unable, at this time, to provide any precise interpretation of the relative index numbers in terms of real values in the field. Therefore, such differences are not very meaningful at present. Differences encountered in our comparisons cannot be attributed to elevation since both the stations used are, for all practical purposes, at the same distance above sea level.

In an analysis of records where danger-rating data have been calculated from the new as well as the old tables and the two types of data are pooled, some precautions should be taken. If the primary interest is in relative differences and relationships, then no further adjustments need to be made. The data can be used as found. However,

Table 3.--*Difference in buildup-index values based on new and standard fuel moisture tables, by index ranges*

Buildup index range	Maximum plus difference	Maximum minus difference	Average difference	Number of cases
0-19	9	-6	0.1	370
20-39	13	-5	.6	222
40-59	8	-8	-2.6	101
60-79	1	-11	-2.7	83
80-99	3	-14	-5.6	42
100-119	1	-12	-7.4	40
120-139	1	-12	-3.5	15
140-159	2	-1	-.3	12
160-179	--	-3	-2.0	8
180-199	--	-4	-3.6	7
200-219	--	-5	-4.0	13
220+	--	-3	-2.5	2

Note: Difference equals index value calculated with new fuel moisture tables minus index value calculated with standard fuel moisture.

if there is a concern regarding specific index values, then perhaps all index values should be calculated on a common basis to insure a more precise analysis result. On the other hand, natural variation within an area being represented by such data may well eliminate the need for a common calculation basis for any analysis. The eventual application of results will dictate whether data are pooled when index values are a result of mixed new table and standard table calculations or whether they are placed on a common basis using one table or the other.

Tables of moisture content of fine fuels have been provided in the appendix. Versions have been prepared for the cured, transition, and green vegetative stages of fuel. Although all comparisons were based on cured vegetation tables, deviations in the less flammable stages of plant maturation should not be as critical. Even though these tables were constructed for use in Alaska, they could easily be used anywhere the NFDRS is employed. The user must, however, be aware of and able to accept the variations noted in our comparisons.

APPENDIX

Table 4.--*Effect of moisture on the rate of germination in herbaceous species*

(In percent)

		Dewpoint temperature (degrees F.)																	
Dry bulb temperature (degrees F.)		-15	-10	-5	0	5	10	15	20	25	30	35	40	45	50	55	60		
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to
		-11	-6	-1	4	9	14	19	24	29	34	39	44	49	54	59	64	69	74
105 - 109	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100 - 104	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
95 - 99	1	1	1	1	1	1	1	1.5	1.5	1.5	2	2	2.5	2.5	3	3.5	4	4.5	5
90 - 94	1	1	1	1	1	1.5	1.5	1.5	1.5	2	2	2.5	2.5	3	3.5	4	4.5	5	5.5
85 - 89	1	1	1	1	1.5	1.5	2	2	2.5	2.5	3	3	3.5	4	4.5	5	5.5	6	7
80 - 84	1	1.5	1.5	2	2	2.5	3	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	9
75 - 79	1.5	1.5	1.5	2	2	2.5	3	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	9
70 - 74	1.5	2	2	2.5	2.5	3	3	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	9
65 - 69	2	2	2.5	2.5	3	3.5	4	4	4	5	5.5	6	6	7	8	9	10	11	12
60 - 64	2.5	2.5	3	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	9	10	11	12	13
55 - 59	3	3	3.5	4	4.5	5	5.5	6	6	7	8	9	10	11	12	13	14	15	16
50 - 54	3.5	3.5	4	4.5	5	5	6	6.5	7.5	8.5	9.5	11	13	16	30+				
45 - 49	4	4.5	5	5.5	6	7	8	9	10	11	13	17	30+						
40 - 44	4.5	5.5	6	6.5	7.5	8.5	9.5	10	12	14	18	30+							
35 - 39	5.5	6.5	7	8	9	10	11	13	15	19	30+								
30 - 34	7	7.5	8.5	9.5	10	12	14	17	21	30+									
25 - 29	8	9	10	11	13	15	18	22	30+										
20 - 24	10	11	12	14	16	19	24	30+											
15 - 19	11	13	15	17	20	27	30+												
10 - 14	14	16	18	22	27	30+													

Fine-fuel
moisture
content

(percent)

Drying
factor

16.0 or more
10.0 - 15.9
7.0 - 9.9
5.0 - 6.9
4.0 - 4.9
3.0 - 3.9
2.9 or less

0
1
2
3
4
5
7

Table 5.--Fine-fuel moisture content--transition in the next stage

(In percent)

		Dewpoint temperature (degrees F.)																Drying factor																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
		-15 to -11		-10 to -6		-5 to -1		0 to 4		5 to 9		10 to 14		15 to 19		20 to 24			25 to 29		30 to 34		35 to 39		40 to 44		45 to 49		50 to 54		55 to 59		60 to 64		65 to 69		70 to 74		75 to 79		80 to 84		85 to 89		90 to 94		95 to 99		100 to 104																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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Fine-fuel moisture content (percent)

21.0 or more
15.0 - 20.9
12.0 - 14.9
10.0 - 11.9
9.0 - 9.9
8.0 - 8.9
7.9 or less

Table 6. -- *Relative humidity and dewpoint depression at 32°*

(In percent)

Dry bulb temperature (degrees F.)	Dewpoint temperature (degrees F.)																Fine-fuel moisture content (percent)	Drying factor
	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	11 to 14	12 to 14	13 to 14	20 to 24	25 to 29	30 to 34	35 to 39	40 to 44	45 to 49	50 to 54		
105 - 109	11	11	11	11	11	11	11	11	11	11	11	12	12	12	12	12	13	13
100 - 104	11	11	11	11	11	11	11	11	11	11	12	12	12	12	12	13	13	14
95 - 99	11	11	11	11	11	11	11	11	11	12	12	12	12	13	13	13	14	15
90 - 94	11	11	11	11	11	11	11	11	11	12	12	12	12	13	13	14	15	16
85 - 89	11	11	11	11	11	11	11	11	11	12	12	12	12	13	13	14	15	16
80 - 84	11	11	11	11	11	11	11	11	11	12	12	12	12	13	13	14	15	16
75 - 79	12	12	12	12	12	12	12	12	12	13	13	13	13	14	14	15	16	17
70 - 74	12	12	12	12	12	12	12	12	12	13	13	13	13	14	14	15	16	17
65 - 69	12	12	12	12	12	12	12	12	12	13	13	13	13	14	14	15	16	17
60 - 64	13	13	13	13	13	13	13	13	13	14	14	14	14	15	15	16	17	18
55 - 59	13	13	13	13	13	13	13	13	13	14	14	14	14	15	15	16	17	18
50 - 54	14	14	14	14	14	14	14	14	14	15	15	15	15	16	16	17	18	19
45 - 49	14	15	15	15	15	15	15	15	15	16	16	16	16	17	17	18	19	20
40 - 44	15	16	16	16	16	16	16	16	16	17	17	17	17	18	18	19	20	21
35 - 39	16	17	17	17	17	17	17	17	17	18	18	18	18	19	19	20	21	22
30 - 34	17	18	18	18	18	18	18	18	18	19	19	19	19	20	20	21	22	23
25 - 29	18	19	19	19	19	19	19	19	19	20	20	20	20	21	21	22	23	24
20 - 24	20	21	21	21	21	21	21	21	21	22	22	22	22	23	23	24	25	26
15 - 19	21	23	23	23	23	23	23	23	23	24	24	24	24	25	25	26	27	28
10 - 14	24	26	26	26	26	26	26	26	26	27	27	27	27	28	28	29	30	31

0
1
2
3
4
5
7

26.0 or more
20.0 - 25.9
17.0 - 19.9
15.0 - 16.9
14.0 - 14.9
13.0 - 13.9
12.9 or less

PNW-110

August 1969



INCREASES IN MAXIMUM STREAM TEMPERATURES AFTER SLASH
BURNING IN A SMALL EXPERIMENTAL WATERSHED

by

Al Levno, *Forest Research Technician*

and

Jack Rothacher, *Principal Hydrologist*

ABSTRACT

The first year after slash was burned on a 237-acre clearcut watershed in the Cascade Range of Oregon, average maximum water temperatures increased 13°, 14°, and 12° F. during June, July, and August. A maximum stream temperature of 75° F. persisted for 3 hours on a day in July.

A previous report^{1/} describing changes in maximum water temperature was prepared after all logs were removed but before slash was burned on a 237-acre clearcut watershed in the H. J. Andrews Experimental Forest. The present report summarizes changes that occurred in maximum stream temperatures during the first year after the slash was burned. Although slash may be left unburned or other methods used to dispose of this waste material, broadcast burning is still the commonest method for slash disposal after logging.

^{1/}

Levno, Al, and Rothacher, Jack. Increases in maximum stream temperatures after logging in old-growth Douglas-fir watersheds. Pacific Northwest Forest and Range Exp. Sta. USDA Forest Serv. Res. Note PNW-65, 12 pp., illus. 1967.

THE STUDY

The clearcut watershed was logged during 1962 to 1966. Logging slash was broadcast burned in October 1966 (fig. 1). Weather conditions were favorable for burning, and virtually all the smaller slash and understory vegetation was consumed by the fire. After the slash fire, larger logs remaining in the lower third of the main stream channel were hand cleared from the immediate streambed (fig. 2), leaving the stream channel exposed to direct sunlight.



Figure 1.—Clearcut watershed after slash burning, H. J. Andrews Experimental Forest.



Figure 2.—Stream channel after slash burning and hand clearing, H. J. Andrews Experimental Forest.

The characteristics of this and two other watersheds being studied on the H. J. Andrews Experimental Forest are covered in detail by Rothacher et al.^{2/} The watersheds originally supported a dense stand of old-growth Douglas-fir forest on steep northwest-facing topography. Wet winters and dry summers are typical on the west slopes of the Cascade Range of Oregon. Summer air temperatures

^{2/} Rothacher, Jack, Dyrness, C. T., and Fredriksen, Richard L. Hydrologic and related characteristics of three small watersheds in the Oregon Cascades. USDA Forest Serv. Pacific Northwest Forest & Range Exp. Sta., 54 pp., illus. 1967.

occasionally exceed 100° F. Average maximum air temperature increases from 80° F. in June to 93° F. in July and August and drop again to 74° F. in September. The average numbers of full sunny days for June, July, August, and September are 18, 24, 20, and 21, respectively. Most of the area is below 3,000 feet in elevation and generally receives the major portion of the annual 90 inches of precipitation as rain.

Although the narrow stream channels have been cut to bedrock along most of their length, the rock, under undisturbed forest conditions, is generally covered with a thin veneer of gravel, woody debris, and vegetation. High winter flows, which may occasionally exceed 50 cubic feet per second (c.f.s.), drop to under 0.05 c.f.s. in late summer. Although the streambed gradient is steep and contains sharp rises which obstruct fish passage, trout are found in the lower reaches of some of the streams in the area. Downstream obstructions exclude anadromous fish.

Weekly maximum and minimum water temperatures have been recorded at the gaging station at the mouth of each experimental watershed since 1959, a period including both before and after harvesting conditions. Beginning in October 1966, water temperatures were recorded hourly on punched tape. Weekly maximum water temperatures were determined from the hourly data.

Data on water temperature increases, based on a linear regression relationship computed between two watersheds while both were undisturbed, is shown in figure 3. This relationship permits prediction of water temperatures on one watershed from temperatures measured on the other. After one watershed was modified (logged and burned in this case), measured water temperatures were compared with predicted temperatures based on a still undisturbed control watershed.

Standard error of the estimate for the after-burning regression was 3.3° F., considerably higher than the error of 1.3° F. for the before-logging regression. Since stream temperature is controlled primarily by direct sunlight, the increased variation indicates greater fluctuation in solar radiation received by the stream in the burned watershed. The shaded, unlogged stream receives more nearly the same amount of radiation on a bright, sunny day as on a cloudy day.

Figure 4 presents the average maximum temperatures measured the year following burning and a predicted curve of temperatures that would have been expected had the watershed not been logged or burned.

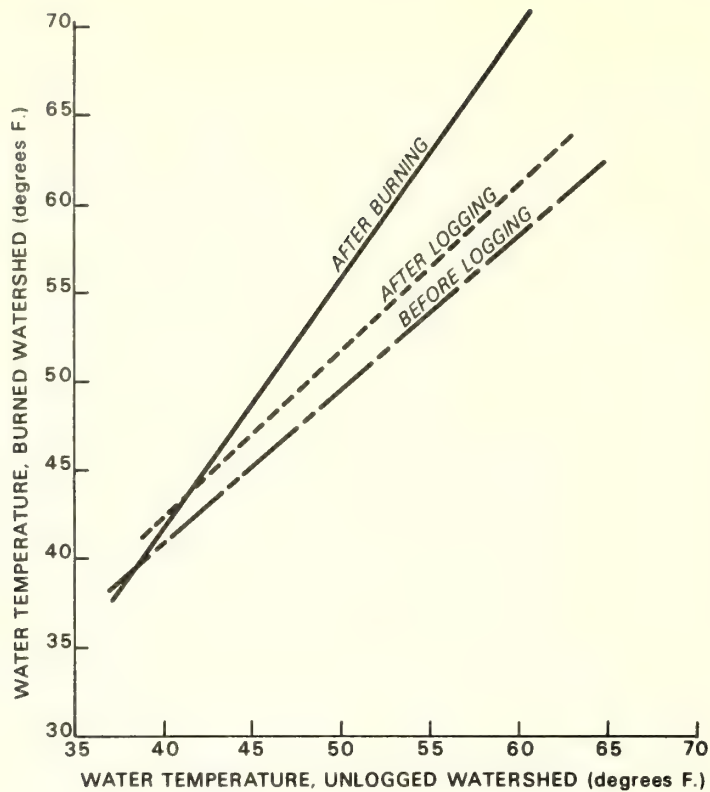


Figure 3.—Maximum weekly water temperatures on the burned watershed before logging, after logging, and after slash burning in relation to temperatures recorded on the unlogged watershed.

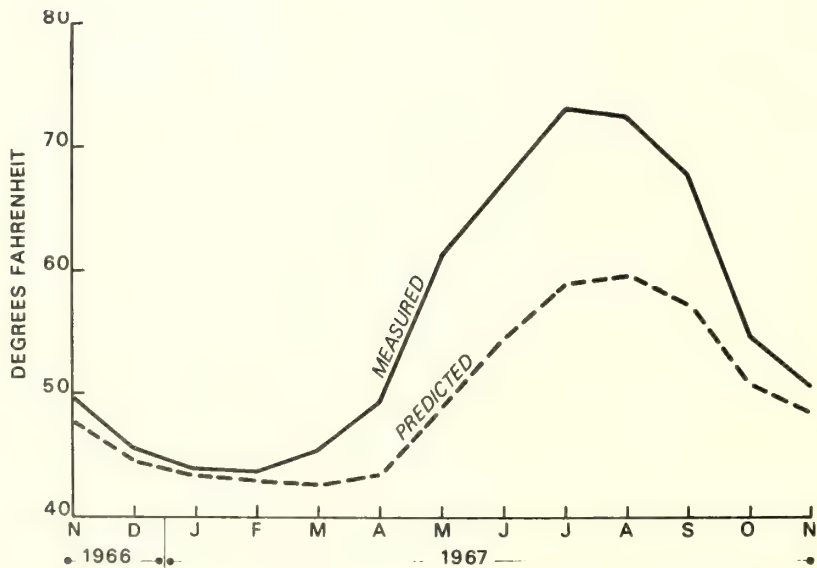


Figure 4.—Measured and predicted average maximum water temperatures on a clearcut watershed following logging and burning, H. J. Andrews Experimental Forest.

Average maximum water temperatures were highest during June, July, and August, 67°, 73°, and 72° F., respectively. This is an increase of 13°, 14°, and 12° F. over the predicted average of 54°, 59°, and 60° F. for the same period.

The maximum water temperature that had been recorded in the burned watershed before logging was 65° F. On June 15, the first year following slash burning, water temperatures in excess of 65° F. began occurring and, except for 6 cloudy days, continued daily until September 22, a total of 86 days. The average duration of temperatures over 65° F. was 10.2 hours per day. Total number of hours at 66° F. and above was 889. The maximum temperature attained, 75° F., persisted for 3 hours on July 3, 1967, during a very warm period when maximum air temperatures varied from 97° to 107° F. Total number of hours for water temperatures from 66° to 75° F. are presented in figure 5.

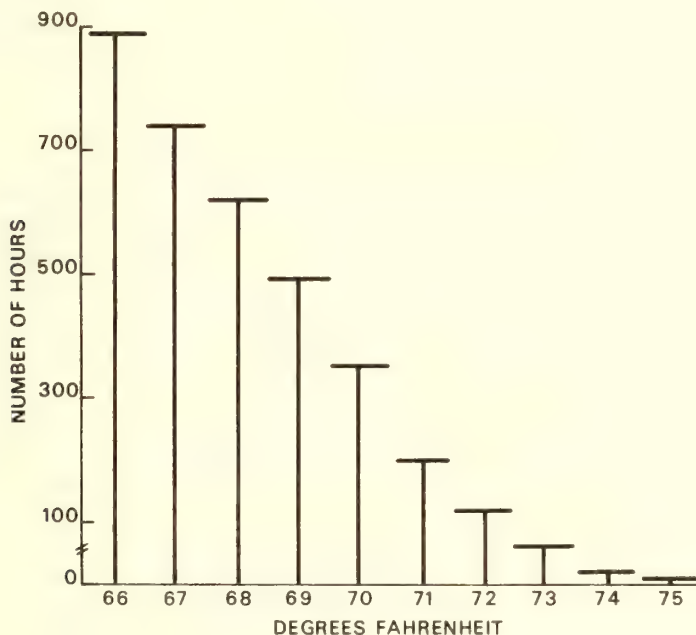


Figure 5.—Total number of hours of high water temperatures (66° to 75° F.) during the first year following slash burning on the H. J. Andrews Experimental Forest.

The longest period of temperatures continuously above 65° F. was 17 hours. This occurred several times during early July, beginning about 9 o'clock in the morning and lasting until 1 or 2 o'clock in the morning of the next day. Temperature would then drop to 62° to 64° F. and begin rising sharply when sunlight again reached the water surface.

DISCUSSION

Data from this and other studies clearly indicate that the water temperature regime may be changed when timber harvest removes the shade provided by streamside vegetation. Temperature increases are directly related to the amount of shade removed and the surface area of stream exposed to direct sunlight. This is due primarily to the energy increase created when the low-intensity, diffuse light of a stream under the forest is changed by canopy removal to direct solar radiation.

Surviving understory shrub vegetation and logging debris adjacent to a stream may provide shade which will cushion the solar radiation impact after canopy removal and lessen the rise in stream temperature. As reported in the previous note (see footnote 1), clearcut logging increased maximum water temperature only 4° F. after all merchantable logs had been removed but before slash burning and stream clearance. In a patch-cut watershed, no significant increase in maximum water temperature was recorded after logging until a debris slide in a section of the channel destroyed all streamside vegetation. The resulting exposure to direct solar radiation caused increases of 12° F. in the stream's temperature.

Burning, which removes all protective stream cover, also increases solar radiation on the stream, causing a marked rise in water temperature. Maximum water temperature increases recorded in this study compare closely with those measured in the Oregon Coast Ranges.^{3/} After the 175-acre clearcut Needle Branch Watershed was burned, Brown and Krygier found the mean-monthly maximum water temperatures were 70°, 71°, and 72° F. during June, July, and August. These temperatures were 14° F. above those in the adjacent unlogged watershed. On the H. J. Andrews Experimental Forest, the after-burning increases in water temperature were 13°, 14°, and 12° F. for the same months.

Temperatures of small streams respond very quickly to solar radiation. Brown and Krygier, in discussing temperature change processes, pointed out that exposure of the stream surface to direct solar radiation is the principal cause of high water temperature. In the study on the H. J. Andrews Experimental Forest, water temperature began to increase immediately after sunlight reached the water surface in the morning and to cool again as soon as direct sunlight left the water surface in the afternoon. Although greater exposure of the

^{3/}

Brown, George W., and Krygier, James T. Changing water temperatures in small mountain streams. J. Soil & Water Conserv. 22(6):242-244, illus. 1967. Also, personal communication with the authors.

study stream after the slash was burned drastically increased the maximum stream temperatures, the duration of the highest temperatures was relatively short. The maximum temperature of 75° F. persisted for only 3 hours. Water temperatures above 65° F., the prelogging maximum, persisted for 17 hours several times in July.

During June through September, water temperature in the burned watershed was above 65° F. for 889 hours. Thus, the stream exceeded the previously recorded maximum of 65° F., measured before logging and burning, for 30 percent of the time during the summer period, or about 10 percent of the total time during the year. Water temperature did drop below the preburning maximum each night. Daily minimums were 64° F. or below, averaging 60.8° F. during the June through September period.

The large increases reported in this study may not be as great in downstream areas. As a consequence of the patch-cut logging system used in the Pacific Northwest, streams from forested areas mingle with those from exposed areas and flow into larger streams, thus diluting the warmed water. Also, water cools some as it passes from an exposed area into a shaded stretch (see footnote 1).

The principal effect of land management practices may be largely in upstream areas, often important fish habitats. The consequences of these practices require further study in terms of the stream ecosystem. As yet, their effect on algal growth, on insect and fish habitat, and on other aspects of water resources is not completely understood.

PNW-111

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HYDROLOGIC PROPERTIES OF SOILS ON THREE SMALL WATERSHEDS
IN THE WESTERN CASCADES OF OREGON

by

C. T. Dyrness, Principal Soil Scientist



ABSTRACT

Detailed soil mapping on three small experimental watersheds resulted in the delineation of eight soil series and 46 mapping units. All soils were of loamy texture and most showed minimal amounts of profile development. With one exception, rates of water movement through saturated soil cores were found to be very high. Percolation rates measured for surface horizons were unusually rapid due to the very porous and highly aggregated nature of these layers. Retention and detention water storage capacity values determined for the surface 4 feet of soil were extremely variable within individual soil series. The single most important factor causing variation in storage capacity values was stone content of the soils. Each of the four most widespread soil series was divided into two new soil units on the basis of stone content. The result was soil units with substantially reduced variation in water storage capacity values. Average retention storage capacity values for the surface 4 feet of soil ranged from approximately 6 to 14 inches and average detention capacities varied from about 8 to 14 inches. Maximum storage capacity available at the end of the summer dry season is estimated to range from about 30 to 40 percent of the total retention capacity values for these soils.

Long-term studies are underway on three experimental watersheds in the H. J. Andrews Experimental Forest (4).^{1/} These studies are aimed at determining the effects of road construction and two types of logging on water production and quality. An investigation of the soils on these watersheds was initiated during the summer of 1963 to provide information which would aid in the correct interpretation of the effects of logging on runoff quantity and quality.

^{1/} Underlined numbers in parentheses refer to Literature Cited, p. 16.

The H. J. Andrews Experimental Forest is located in the Western Cascades geologic province approximately 45 miles east of Eugene, Oregon. The three experimental watersheds are contiguous and are 149, 237, and 250 acres in size. Topography is mature, with sharp ridges and steep slopes. The geologic pattern in the area is quite complex, with the principal rock types being pyroclastics (tuffs and breccias), andesites, and basalts. The vegetation type consists of old-growth Douglas-fir stands mixed with substantial amounts of western hemlock and western redcedar.

Objectives of this study included the classification and detailed mapping of the soils and the characterization of the mapping units with special emphasis on hydrologic properties. Some of the questions we hoped the present study would answer are:

1. What are the moisture storage capacities (both retention and detention) of the soils?
2. Which soils have highest percolation rates?
3. Do watershed soil properties suggest the occurrence of large-scale subsurface waterflow? And, perhaps most fundamentally,
4. Does a conventional soil survey provide adequate hydrologic stratification?

FIELD METHODS

The first step in this study was the detailed mapping of soils on the three watersheds. The mapping units were based on phases of series. Units of this nature are the most common in National Cooperative Soil Surveys. Three main types of phases were used: (1) stoniness, (2) landform, and (3) slope. Conventional methods of soil survey were followed except that more frequent observations of the soil profile were made and minimum size of delineations was only 1 acre. All mapping was carried out on a map with a scale of 16 inches to a mile.

During the summer of 1962, survey party leader Freeman Stephens and assisting soil scientists from the Portland Regional Office of the Forest Service, U.S. Department of Agriculture, had mapped the soils on the entire H. J. Andrews Experimental Forest at

a scale of 4 inches to the mile. At that time, six series were identified and mapped on the experimental watersheds. This survey was the basis for the more detailed survey conducted in this study.

A total of 85 complete soil profile descriptions have been made. Procedures outlined in the Soil Survey Manual (5) were followed. Fifty-three of these profiles were sampled by horizon. Bulk samples were collected from each horizon and, where excessive stoniness did not prevent it, undisturbed core samples were also taken. An attempt was made to describe and sample representative soils at widely scattered locations over the entire three watersheds. All important soil mapping units were sampled at least once, and the more important units were sampled at several locations.

LABORATORY METHODS

The following laboratory determinations were carried out on all samples: particle-size distribution by the Bouyoucos hydrometer method; moisture-tension determinations at 1/3, 1, 5, and 15 atmospheres; total organic matter content by the modified Walkley-Black method (1); and pH by a glass electrode pH meter and a 1:1 soil-water paste. Particle density by the pycnometer method was determined for selected samples. Determinations made for all undisturbed core samples included bulk density and percolation rate. The apparatus used for determining the rate of water percolation through soil cores was a modification of the design suggested by Hoover et al. (3).

RESULTS

Soil Units

Eight soil series have been proposed and mapped on the watersheds. These series have not been coordinated into the system of the National Cooperative Soil Survey so that changes in names and definitions are possible. Two series have not been given names but are referred to by the letters A and M. Further subdivisions within the series, based on characteristics of stoniness, slope, and landform, have resulted in the use of 46 mapping units (table 1). The two most widely occurring series are the Limberlost and A. These are followed by the Frissell and Budworm series in decreasing order of occurrence. The McKenzie River, Slipout, M, and Flunky series all occupy rather limited areas within the three watersheds.

Table 1.--*Soil series, number of mapping units, and number of profiles described and sampled in three small watersheds*

Soil series	Number of mapping units	Profiles described	Profiles sampled
McKenzie River	4	12	3
Frissell	4	8	7
Slipout	2	6	2
Budworm	6	12	7
Limberlost	14	16	13
M soil	3	4	1
A soil	11	20	18
Flunky	2	7	2
Totals	46	85	53

All soils in the watersheds tend to be of loamy texture and most show very little evidence of extensive profile development (table 2). With the exception of the McKenzie River and Slipout series, horizons beneath the A1 are generally only weakly expressed and are often very difficult to detect. Especially on steep slopes, most soils are developing in creep material and colluvium, and profiles are markedly immature. Underlying colluvial deposits are often very deep, and in some areas solid bedrock may be at least 50 feet beneath the surface. Surface soils are uniformly well structured and extremely porous with some exhibiting "shotty" concretions. Most of the soils tend to be at least moderately stony, with stone content showing a positive correlation with slope.

The McKenzie River and Frissell soils are derived from reddish tuffs and breccias. The McKenzie River is a well-drained Reddish Brown Lateritic soil generally occurring on moderate slopes. This soil is generally only moderately stony, and depth to weathered parent material is usually over 3 feet. The Frissell is a well-drained soil formed in colluvium from reddish breccias in ridgetop and steep slope positions. It is classified as a Regosol--i. e., a soil developed in unconsolidated parent materials, showing little profile development beyond the formation of a surface horizon.

Table 2.--Particle-size distribution, textural class, and stone content of eight soil series occurring in three small watersheds

Soil series	Surface soil						Subsoil						Textural class									
	Percent sand			Percent silt			Percent clay			Percent stones (by volume--weighted average for surface 48 inches of soil)				Percent sand			Percent silt			Percent clay		
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range		Mean	Range	Mean	Range	Mean	Range	Mean	Range	
																						Mean
From reddish tuffs and breccias:																						
McKenzie River (10) ^{1/}	34.4	23.4-56.3	38.2	26.0-44.2	27.4	17.7-34.4	22.4	4.6-50.5	16.7	8.1-34.1	41.7	37.3-45.4	41.6	28.6-51.8	Silty clay							
Frissell (7)	35.0	18.5-61.7	40.4	19.2-50.6	24.6	16.1-32.2	43.4	17.0-81.8	31.1	16.6-53.7	43.4	26.3-50.7	25.2	18.6-32.8	Loam							
From greenish tuffs and breccias:																						
Slipout (2)	40.8	30.6-50.9	37.2	26.3-48.1	22.0	21.3-22.8	15.2	9.9-20.5	26.2	20.4-31.9	37.5	31.6-43.4	36.3	36.2-36.5	Clay loam							
Budworm (7)	37.6	31.4-43.6	39.6	34.3-54.3	22.8	14.3-27.3	24.6	8.9-59.7	25.3	18.6-30.8	47.0	42.4-53.2	27.7	21.5-34.0	Clay loam							
Limberlost (13)	38.0	25.8-64.7	39.2	19.4-50.5	22.8	16.0-26.6	46.6	15.7-72.3	35.9	22.3-59.6	40.5	25.7-50.9	23.6	14.7-31.6	Loam							
From basalt:																						
Flunky (2)	48.6	33.4-63.7	36.7	27.7-45.8	14.7	8.6-20.8	76.2	75.9-76.6	49.4	45.0-53.9	31.6	29.8-33.3	19.0	16.3-21.7	Loam							
From andesite colluvium:																						
A soil (15)	47.0	34.9-59.4	32.1	22.5-41.0	20.9	11.0-27.9	48.0	6.2-72.7	38.9	18.2-60.6	39.4	25.7-73.8	21.7	8.0-34.3	Loam							
From mixed colluvium:																						
M soil (1)	36.4	--	--	36.4	--	27.2	--	--	--	15.5	--	--	--	47.7	--	--	36.8	--	--	Silty clay		

^{1/} Numerals in parentheses indicate number of soil profiles in sample.

The Slipout, Budworm, and Limberlost soils are derived from greenish tuffs and breccias. The Slipout is an imperfectly drained Yellowish Brown Lateritic soil formed in colluvial materials on gentle slopes. Slipout soils are generally at least 3 feet in thickness and show mottling in the subsoil as evidence of impeded drainage. The Budworm soil is also classified as a Yellowish Brown Lateritic; however, unlike the Slipout, it is moderately well drained and shows less profile development. The Limberlost series is a well-drained Regosol formed in colluvium from greenish tuffs and breccias. It is generally found on steep slopes and ridgetops.

The M soil is from mixed colluvium and occupies only a few acres near the mouth of one of the watersheds. It is classed as a well-drained Reddish Brown Lateritic soil.

The A soil is from andesite colluvium and is a well-drained Regosol developed in deep deposits of colluvium. Stone content of both the soil and parent material is generally high. Depth to parent material ranges from about 15 to 24 inches.

The Flunky soil is a well-drained Lithosol derived from basalt. Fractured basalt bedrock is generally within 2 feet of the surface.

Rate of Soil Water Movement

The rate of waterflow through saturated soil cores was determined for individual horizons within 18 profiles (fig. 1). Since these determinations were run on small soil samples contained in rings only 2 inches in diameter, the values presented probably have only an approximate relationship to rates which could be expected under field conditions. However, the values do provide an index of the relative permeability of individual soil horizons and also make it possible to compare soils as to their ability to transmit water under saturated conditions.

Values shown in figure 1 indicate, that with only one exception, these soils are extremely permeable and, therefore, transmit water rapidly. As would be expected, the surface horizons were found to have the highest percolation rates. These rates were so high in the case of the A, Frissell, and Budworm soils that it was impossible to maintain a head of water on the surface of the soil core. These high permeability rates reflect the extremely porous and highly aggregated nature of the surface soil layers. Subsoil layers were also highly

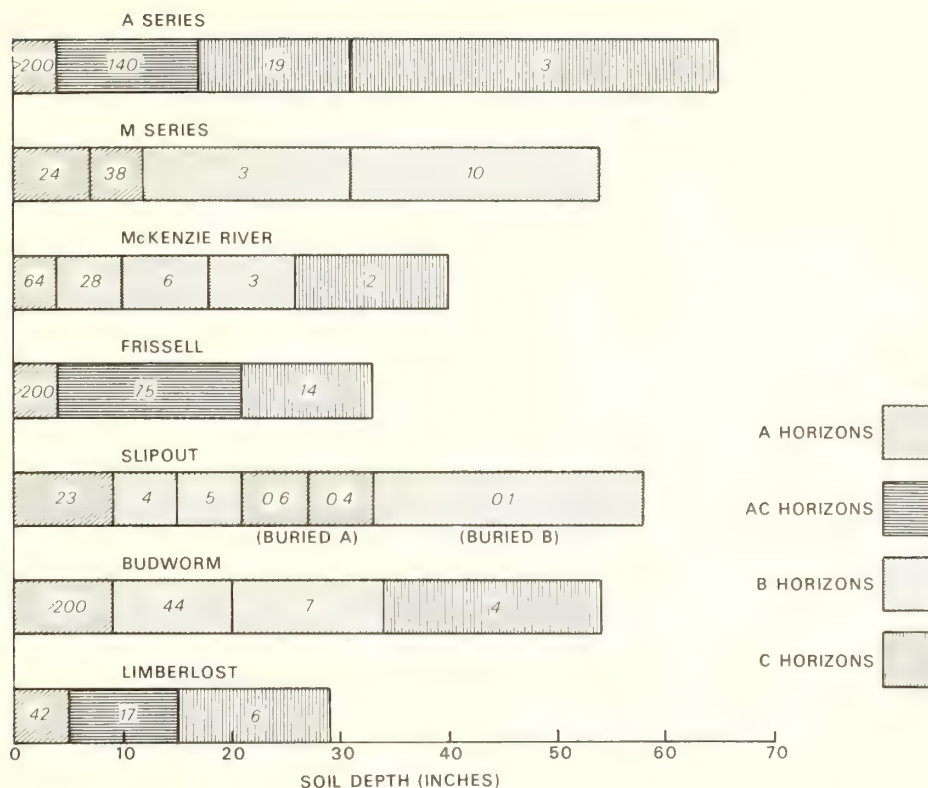


Figure 1.--Percolation rate (inches per hour) by horizon for seven representative profiles.

permeable in the saturated state with the single exception of the Slipout soil series (fig. 1). As a result of these layers, the Slipout soil is imperfectly drained and portions of the lower solum are generally saturated during the wettest periods of the year. All other series have subsoil percolation rates sufficiently high that extensive saturation or near saturation would not be expected except for very short periods during prolonged rainstorms.

Porosity relationships for the same seven soil series are illustrated in figure 2. Surface soil horizons are extremely porous--from two-thirds to three-fourths of the total volume is made up of voids. In addition, generally well over half of the total porosity are voids of noncapillary size. These large pores are especially important since they conduct water under saturated conditions.

Subsoil porosity is also high in these soils (fig. 2). All soils possess at least 50 percent pore space in the subsoil. In almost all

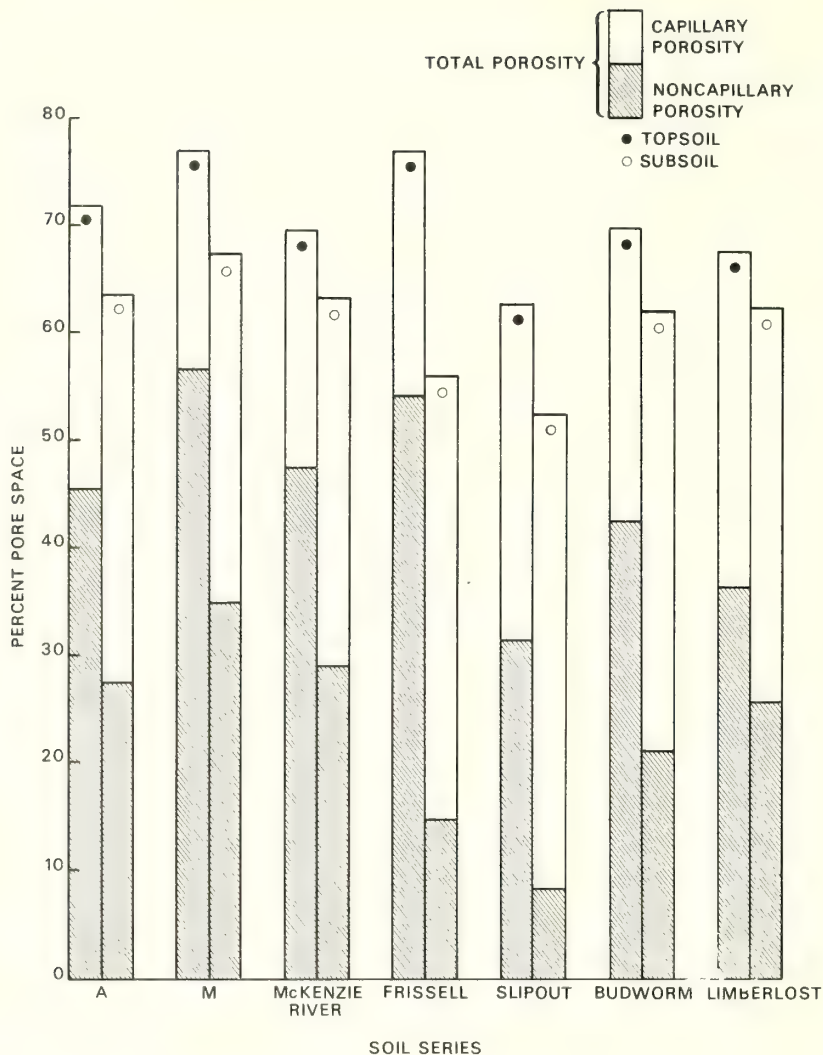


Figure 2.--Soil porosity characteristics of seven soil series.

cases the predominant pore size class is the capillary or, in other words, the smaller voids which are not involved in the movement of gravitational water. The slow rate of water movement through the Slipout subsoil can be attributed to the fact that this layer contains only about 8 percent by volume of noncapillary-size pores. We can conclude, then, that the observed decrease in water movement rates through the subsoil is not so much due to decreases in total porosity as it is to shifts from predominantly noncapillary porosity to capillary porosity.

Soil Water Storage Capacity

Watershed managers are generally concerned with two types of soil water storage capacities: retention and detention capacities. Retention storage refers to water held in capillary-size pores or, in other words, that portion of the total soil water supply at moisture contents of "field capacity" or less. Water in retention storage is generally considered to be available for plants and evaporation, but unavailable as a source of water for streamflow. Water in detention storage is located in the large, noncapillary-size soil pores. Water of this type is found in the soil at moisture contents ranging from "field capacity" to saturation and is, therefore, subject to gravitational pressures.

Storage capacities determined for the eight soil series located in the experimental watersheds are shown in table 3. Mean values for both retention and detention capacity are roughly similar for all series with the exception of the low values found for the Flunky soil and the somewhat higher values found for the Budworm, Slipout (in the case of retention capacity), and M series. The low values for the Flunky soil may be attributed to its shallow, stony profile; whereas the higher values for Budworm, Slipout, and M series are largely the result of relatively low stone contents. Probably the most surprising aspect of the data in table 3 is the wide variation in quantities encountered within series. As an example, retention capacity for Limberlost profiles ranged from 2.61 to 13.25 inches, with detention capacity values ranging from 3.68 to 16.15 inches.

Analyses of variance calculations were carried out on data for the Frissell, Limberlost, A, and Budworm soil series to determine whether or not relationships between series and storage capacity were statistically significant. Because of the wide variation in water storage capacity within series, as indicated in table 3, it is not surprising that the results of these analyses indicated a statistically nonsignificant relationship between soil series and storage capacity. These results indicated that the original attempt to classify the soils into series had failed to provide an adequate basis for stratification into meaningful hydrologic groupings.

After a consideration of the data, it was concluded that probably the single most important factor causing variation in storage capacity values was stone content of the soils. Stone content of sampled watershed soils ranged from about 6 to 82 percent by volume (table 3).

Table 3.--*Retention and detention storage capacities in the surface**48 inches of soil (corrected for stone content)*

Soil series	Number of profiles sampled	Retention capacity (inches)		Detention capacity (inches)	
		Mean	Range	Mean	Range
Frissell	7	8.08	1.94-11.45	10.22	4.59-16.28
Limberlost	12	7.76	2.61-13.25	9.17	3.68-16.15
A soil	14	7.57	3.32-15.45	9.15	5.38-13.83
Budworm	7	12.20	5.38-15.87	12.48	7.99-16.97
Flunky	2	2.90	2.36-3.43	4.81	4.37-5.25
Slipout	2	14.18	12.92-15.44	9.08	7.98-10.18
McKenzie River	2	10.07	7.71-12.43	9.50	6.33-12.68
M soil	1	13.52	-- --	15.81	-- --

Since the majority of these stones were hard, unweathered andesite and virtually impervious to water, it was necessary in all cases to correct storage capacity values for stone content. Thus, a well-defined relationship between stone content and both retention and detention storage capacities is, of course, to be expected. However, what is perhaps unexpected is the extremely close relationship between stone volume and storage capacity which was actually found (figs. 3 and 4). For example, the correlation coefficients indicate that stone content alone explains 80 and 87 percent of the variation observed in retention and detention storage capacity values, respectively. Therefore, we are forced to conclude that factors other than stone content exert very little influence on storage capacity values.

The soil series, as originally defined in this study, are similar to those commonly employed in mapping the soils of forested uplands elsewhere in the Pacific Northwest. Unfortunately, as we have seen, such widely defined soil classification units, especially with respect to stone content, may fail to provide soil groupings satisfactory for management and research purposes. Recently, however, the U.S. Soil Conservation Service (6) introduced a new set of criteria for family groupings based on soil texture and percent by volume of particles coarser than 2 millimeters. Under this system of classification, the four most widespread soils in the experimental area--

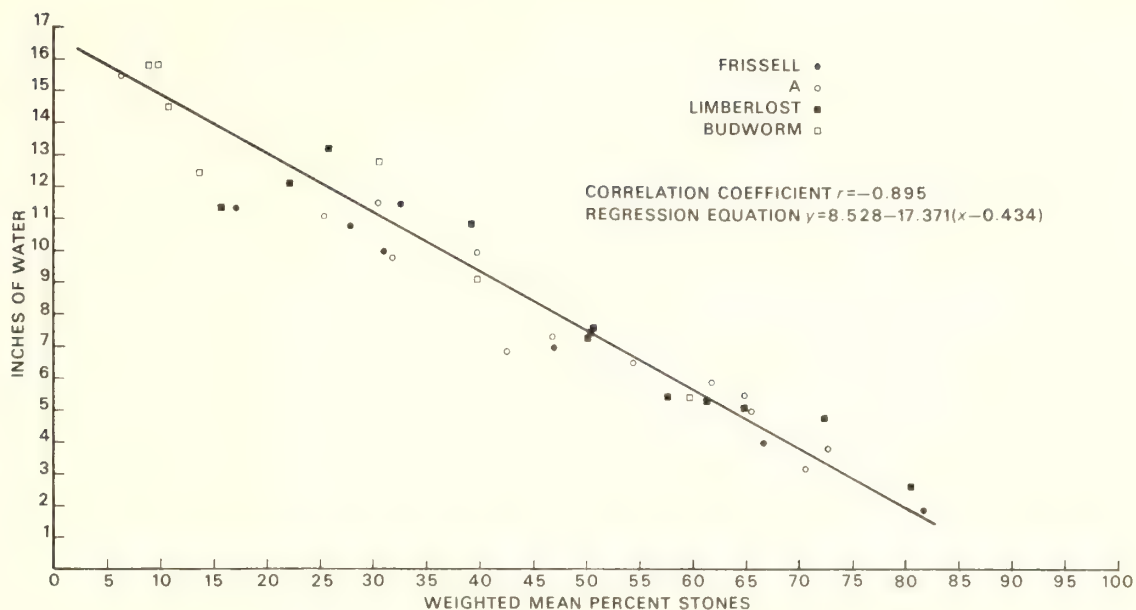


Figure 3.--Retention storage capacity in the surface 48 inches of 40 soil profiles representing four soil series as a function of average stone content.

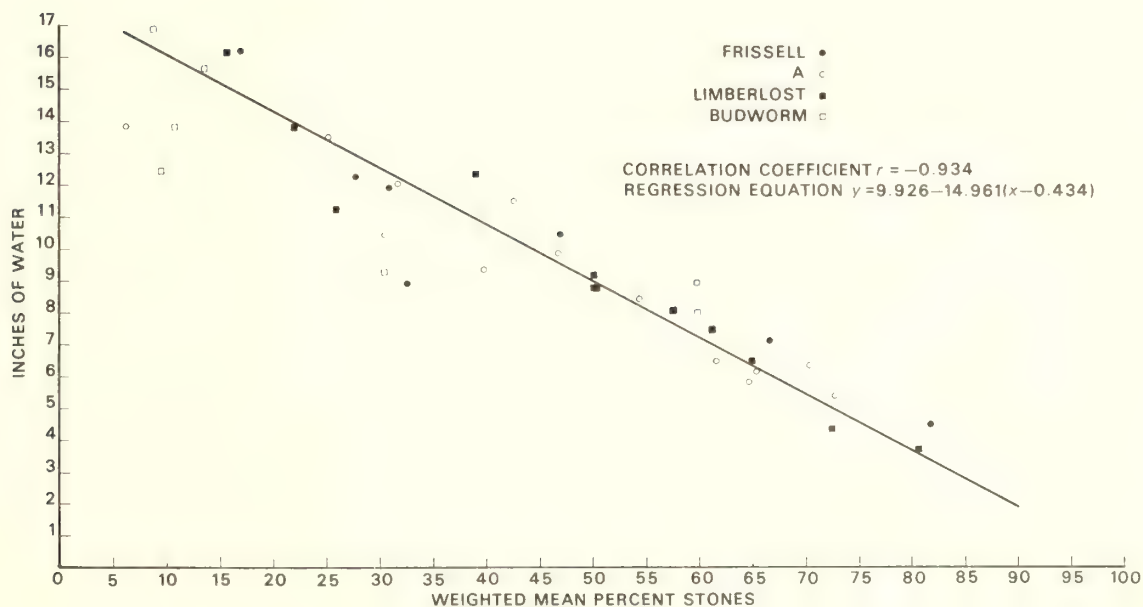


Figure 4.--Detention storage capacity in the surface 48 inches of 40 soil profiles representing four soil series as a function of average stone content.

Limberlost, Budworm, Frissell, and A--must each be divided into two "new series." For these kinds of soils, the "control section" for the particle-size classes is defined as the depth from 10 to 40 inches. All four soils fall within the "fine-loamy" (18 to 35 percent clay) particle-size class when only the finer than 2-millimeter fraction is considered. However, according to this system, fine-loamy soils containing more than 35 percent by volume in the control section of particles coarser than 2 millimeters are placed within a "loamy-skeletal" class. The revised series classification using these criteria is shown in table 4. As indicated, the original soil series name has been reserved for the most commonly occurring particle-size class.

The revised soil series classification resulted in soil units with substantially reduced variation in stone content (table 4). To assess the efficiency of the new classification in grouping soils by water-holding capacity, analysis of variance was again run on retention and detention capacity data. The results indicated a highly significant (at the 1-percent level) relationship between the eight "new" soil series and these two water storage parameters. Therefore, as expected, segregating the soils on the basis of stone content substantially decreased variability in water relationships within soil units. However, as figure 5 shows, despite the improvement, most soil units still exhibit a considerable range in storage capacity values.

As previously pointed out, soil mapping units employed in this study were based on three types of phases: slope, landform, and stoniness. A consideration of mapping unit groupings indicates that they successfully segregate storage capacity values only to the extent to which they reflect stone content differences (table 5). The five soil phase classes shown in table 5 were grouped independently of any consideration of soil series classification. Analysis of variance calculations showed the relationship between retention storage capacity and soil phase classes to be significant at the 1-percent level, whereas significance was at the 5-percent level for detention storage capacity. Although the relationship is far from perfect, the fact that there is any correlation at all may be attributed to the tendency towards increased stoniness with increasing slope in the experimental watersheds.

DISCUSSION

The streams draining the experimental watersheds react quickly to the onset of precipitation and thus, during a storm, their hydrographs show a rapid rise. This quick reaction and rapid rise of the

Table 4.--Revised soil series classification based on the most recent family criteria (6) and percent stone content by volume in the surface 48 inches of soil

Family designation and revised series	Number of profiles	Average stone content (percent by volume)	Range in stone content
Loamy-skeletal:			
Limberlost	9	58	39-80
Loamy-skeletal Budworm	2	50	40-60
Frissell	4	57	31-82
A	11	55	25-73
Fine-loamy:			
Fine-loamy Limberlost	3	21	16-26
Budworm	5	15	9-30
Fine-loamy Frissell	3	26	17-32
Fine-loamy A	3	23	6-32

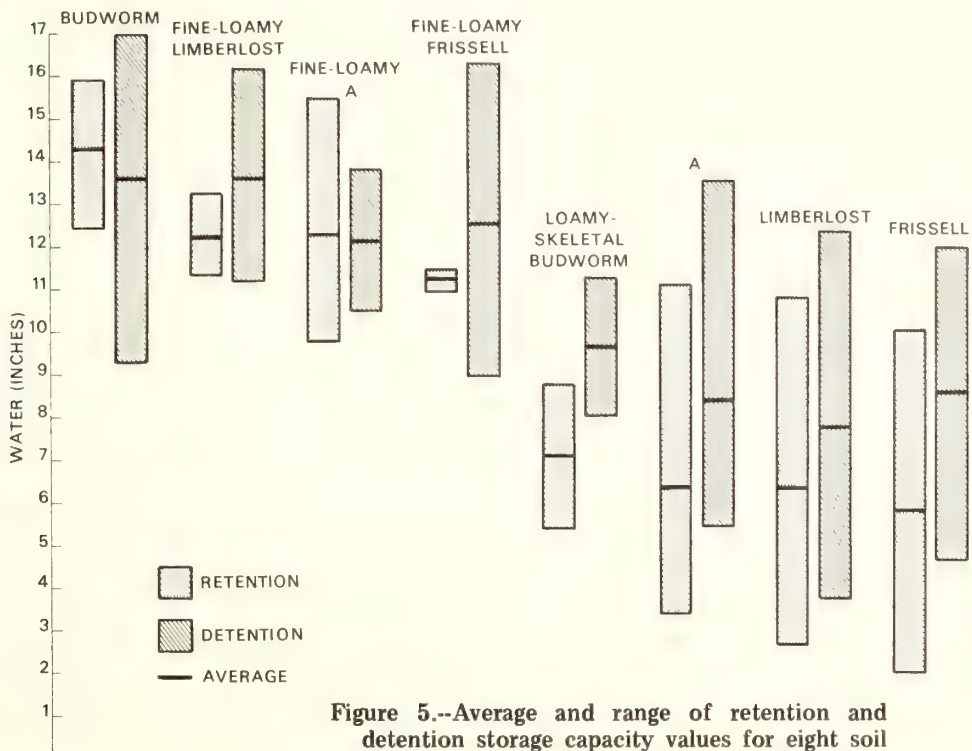


Figure 5.--Average and range of retention and detention storage capacity values for eight soil series.

Table 5.--Retention and detention storage capacities in the surface 48 inches of soil by five phase classes^{1/}

Soil phase class	Number of profiles within the class	Retention capacity (inches of water)		Detention capacity (inches of water)	
		Mean	Range	Mean	Range
Stony phase	8	5.09	1.94-8.75	8.26	3.68-11.25
Uneven slope and bench	10	10.87	4.32-15.81	11.69	7.48-16.97
0- to 40-percent smooth slope and ridge	8	10.67	2.36-15.87	10.61	4.33-15.62
40- to 80-percent smooth slope and ridge	12	9.52	5.10-12.08	10.57	6.52-15.81
> 80-percent smooth slope	9	6.63	3.43-11.32	8.21	4.37-16.15

^{1/} From data for all 47 sampled profiles and eight soil series.

hydrographs are often indicative of the contributions of large-scale overland flow. However, surface runoff during storm periods has not been observed in these watersheds. As a result, it has been necessary to hypothesize shallow and rapid subsurface flow coupled with the effects of steep slopes to account for the observed hydrograph pattern (4). The often extremely high surface permeability rates measured in these soils would certainly tend to lend credence to this hypothesis. Rapid soil water movement toward streams would be expected in soils with such high surface permeability rates plus large proportions of noncapillary-size pores. The exact pattern of water movement through these soils, however, must remain unknown until future research on this problem has been conducted.

It is difficult to interpret soil water storage capacity values without having some information on field soil moisture levels throughout the year. Unfortunately, our knowledge of soil moisture trends on the watersheds is limited to the results of a study confined to a relatively small area of the McKenzie River soil series (4). This limitation is not so serious in the case of detention storage capacity, as we can probably safely assume this storage is filled only during rather lengthy rainstorms and that during the bulk of interstorm periods a very large proportion of detention storage capacity is available. The most puzzling question is, therefore, what portion of the retention storage capacity is available during different periods of the year? In view of the summer dry spell characteristic of the Oregon Cascade Range, we can safely

predict that maximum available retention capacities would occur during the late summer period before fall rains begin. Results for the McKenzie River soil under an old-growth Douglas-fir stand have shown that seldom does soil moisture depletion during the growing season proceed as far as the wilting point (15 atmospheres tension) in the surface 4 feet (4). Therefore, available retention storage capacity in this soil at the end of the growing season may be estimated by subtracting the volume of water remaining in the soil at about 5 to 10 atmospheres from the total retention storage capacity (i. e., volume of water in the soil at one-third atmosphere).

If it is assumed that the maximum drawdown by evapotranspiration during the growing season would be to the 15-atmosphere level, we can then easily estimate maximum available retention storage capacities for the various watershed soils. As an example, values for four representative 4-foot profiles are as follows:

	<u>Total retention storage capacity</u> (Inches)	<u>Available retention storage capacity with depletion to 15 atmospheres tension</u> (Inches)
Budworm	15.88	6.10
Limberlost	13.25	5.22
Frissell	11.45	4.24
A series	15.45	5.88

These calculations, as well as others, indicate that maximum available retention capacity ranges from about 30 to 40 percent of the total retention capacity value.

Any reduction in evapotranspiration during the growing season would substantially reduce available retention capacity below the theoretical maximum. Areas recently logged over would be expected to have soils with lower available capacity due to a markedly reduced transpirational draft. Once again, our knowledge of this reduction for the watershed soils is confined to the McKenzie River series. The first year after clearcut logging, available retention storage capacity was reduced by 4.5 inches. However, by the third year after logging this reduction was only 0.6 inch due to rapid revegetation (2). Further research is needed to define the effects of tree removal on other soils.

This study has pointed up the need for improvement of soil classification and survey techniques in forested uplands. With few exceptions, the original eight soil series encountered on the experimental watersheds exhibited very little difference in such gross

characteristics as texture, structure, plant root distribution, etc. Despite this similarity, however, each series showed a wide range of water movement and, especially, water storage capacity values. Re-definition of four of the soil series on the basis of family criteria resulted in considerable improvement in classification efficiency. This may be attributed to the fact that the resultant eight "new" soil series possessed a substantially reduced range in stone content, compared with the original units. Because of the close correlation between soil water storage capacity values and stone content, the relationship between storage capacity and soil unit then proved to be statistically highly significant. However, even these new soil units contained considerable heterogeneity in physical properties. Thus, there is still room for improvement through the use of carefully chosen soil mapping units or phases. As pointed out in the preceding section, the mapping units used in the present study were only partially successful in classifying the soil for hydrologic purposes. Again, the most glaring weakness of these soil units involved the fairly wide variation in stone content encountered within them.

The results of this study indicate that in areas where stone content is an important soil factor, soil classification and mapping procedures should be designed to yield as much accuracy as possible in the estimation of stone content. This need is especially acute if the soil units are to serve as a basis for making hydrologic interpretations. Unfortunately, a high degree of precision is probably unattainable in many areas because of the substantial local variability in stoniness which is often encountered. However, continuous attempts should be made to improve both classification and mapping procedures in order that the soil units and maps will be of maximum value to the user.

LITERATURE CITED

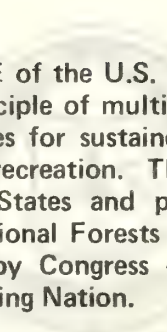
1. Alban, L. A., and Kellogg, M.
1959. Methods of soil analysis as used in the Oregon State College Soil Testing Laboratory. Oreg. Agr. Exp. Sta. Misc. Pap. 65, 8 pp.
2. Fredriksen, R. L.
1967. Summer water balance changes on an old-growth Douglas-fir site after logging. (Abstr.) Northwest Sci. 41: 50.

3. Hoover, Marvin D. , Olson, David F. , Jr. , and Metz, Louis J.
1954. Soil sampling for pore space and percolation. USDA
Forest Serv. Southeastern Forest Exp. Sta. Pap.
42, 28 pp.
4. Rothacher, Jack, Dyrness, C. T. , and Fredriksen, Richard L.
1967. Hydrologic and related characteristics of three small
watersheds in the Oregon Cascades. USDA Forest
Serv. Pacific Northwest Forest & Range Exp. Sta.,
54 pp. , illus.
5. U.S. Bureau of Plant Industry, Soils, and Agricultural Engineering.
1951. Soil survey manual. U.S. Dep. Agr. Handb. 18,
503 pp. , illus.
6. U.S. Soil Conservation Service.
1967. Supplement to soil classification system (7th approx-
imation). U.S. Dep. Agr., 207 pp.

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Pacific
North
West Forest and Range Experiment Station
U.S. Forest Service **RESEARCH NOTE**

PNW-112

October 1969

EFFECTS OF HIGH SOIL DENSITY ON SEEDLING ROOT GROWTH OF
SEVEN NORTHWESTERN TREE SPECIES

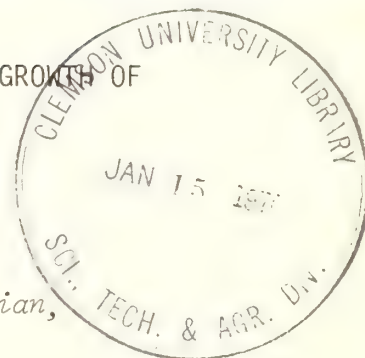
by

Don Minore, *Plant Ecologist,*

Clark E. Smith, *Forest Research Technician,*

and

Robert F. Woollard, *Forest Research Technician*



ABSTRACT

Seedlings of Douglas-fir, Sitka spruce, western hemlock, western redcedar, lodgepole pine, Pacific silver fir, and red alder were grown over soil columns compacted to bulk densities of 1.32, 1.45, and 1.59 grams per cubic centimeter. In 2 years, the roots of lodgepole pine, Douglas-fir, red alder, and Pacific silver fir penetrated soil columns that the roots of Sitka spruce, western hemlock, and western redcedar did not.

INTRODUCTION

Species differences in regard to the effects of high soil density on seedling root growth are compared here for seven Northwestern tree species: Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), lodgepole pine (*Pinus contorta*), Pacific silver fir (*Abies amabilis*), and red alder (*Alnus rubra*).

Forristall and Gessel (1955),^{1/} working in Snohomish County, Wash-

ington, concluded that western redcedar roots could grow in a soil bulk density of approximately 1.8 grams per cubic centimeter, and red alder root growth was stopped by a density of approximately 1.5. However, the soil density above which roots do not penetrate varies

^{1/}Forristall, Floyd F., and Gessel, S. P. Soil properties related to forest cover type and productivity on the Lee Forest, Snohomish County, Washington. Soil Sci. Soc. Amer. Proc. 19: 384-389. 1955.

with soil texture (Veihmeyer and Hendrickson 1948),^{2/} and a given bulk density in fine-textured soil limits root growth more than the same density in coarse soil (Lull 1959;^{3/} Raney *et al.* 1955^{4/}). Therefore, limiting bulk density values like those given by Forristall and Gessel probably are valid only for the soils in which they were measured.

Youngberg (1959)^{5/} measured bulk densities of 1.5 to 1.7 on tractor roads where densities in adjacent cutover areas were only 0.87 to 0.98 grams per cubic centimeter. He recorded highly significant differences in height growth of Douglas-fir seedlings planted on and off the roads but did not measure root growth.

MATERIALS AND METHODS

A sandy loam soil (52 percent sand, 31 percent silt, 17 percent clay) was screened, blended, and compacted to three bulk densities in 37-centimeter lengths of plastic sewer pipe 10 centimeters in diameter. A Carver hydraulic press (fig. 1) and small, equal increments of air-dry soil were used to construct a compacted column

30 centimeters deep in each pipe length. The soil in each column was weighed, and weights were converted to an oven-dry basis. Pressures of 34.6, 8.0, and 3.5 kilograms per square centimeter were applied to obtain bulk densities of 1.59, 1.45, and 1.32 grams per cubic centimeter. A perforated plastic tile was cemented to the lower end of each pipe section to create a cylindrical pot. Equal amounts of a 4-to-1 mixture of soil and peat moss were then added to each pot above the compacted soil column, forming a loose top layer 6 centimeters deep.

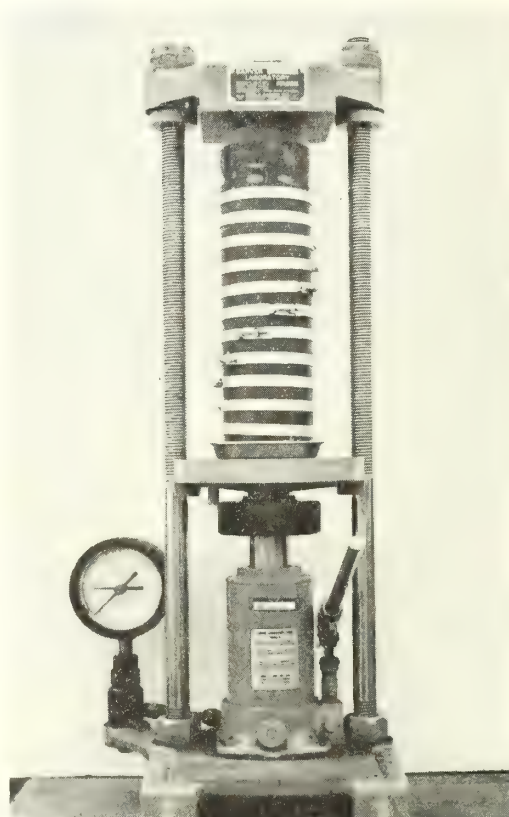


Figure 1.--Carver hydraulic press. A close-fitting wooden cylinder (not shown) compacted soil within the plastic pipe section. Metal rings prevented pipe splitting during compaction.

^{2/}Veihmeyer, F. J., and Hendrickson, A. H. Soil density and root penetration. *Soil Sci.* 65: 487-493. 1948.

^{3/}Lull, H. W. Soil compaction on forest and range lands. U.S. Dep. Agr. Misc. Pub. 768, 33 pp. 1959.

^{4/}Raney, W. A., Edminster, T. W., and Allaway, W. H. Current status of research in soil compaction. *Soil Sci. Soc. Amer. Proc.* 19: 423-428. 1955.

^{5/}Youngberg, C. T. The influence of soil conditions, following tractor logging, on the growth of planted Douglas-fir seedlings. *Soil Sci. Soc. Amer. Proc.* 23: 76-78. 1959.

Seeds from low-elevation, coastal sources were used. Seeds were stratified and germinated in petri dishes, then planted in the loose layer of top soil in May 1967. Seven seedlings of the same species were planted in each pot, and each species-soil density combination was replicated four times. Species and bulk density treatments were completely randomized on a greenhouse bench. Summer temperatures in the greenhouse varied from 16° to 32° C. Each of the 84 pots was weighed and watered three times each week to bring the soil to 1 atmosphere of soil moisture tension--determined on the Richardson pressure membrane apparatus. During 1967, the amounts of water added were computed on a soil weight basis. During 1968, they were computed on a soil volume basis similar to that used by Flocker and Nielsen (1961).^{6/} All pots were fertilized with equal amounts of nutrient solution^{7/} at 2- to 3-week intervals throughout the growing seasons of 1967 and 1968.

Seedlings were thinned to four per pot in August 1967. Pots and seedlings were chilled at 0° to 5° C. for 10 weeks during the winter of 1967-68. Seedlings were thinned to two per pot in March 1968, and a final thinning in April 1968 left one

seedling in each pot. Overwintering mortality and a watering accident reduced the experiment to three replications in 1968.

The pots were broken in September 1968 and rooting depths measured in each soil column. Many roots were found wedged between the pot wall and the compacted soil column (fig. 2). The depths of these roots were measured in addition to the depths of roots which actually penetrated the column itself. Roots were carefully washed free of soil. Roots and shoots were then oven-dried at 65° C. for 48 hours and weighed. All measurements were subjected to factorial analyses of variance.

RESULTS

Average seedling weights and root depths are listed in table 1. Inherent growth differences between species resulted in significant weight differences regardless of bulk density treatment (red alder was always heavier than western hemlock, for example), but significant species X density interactions occurred. When weights were analyzed separately for each species, only western redcedar weights differed significantly between soil density treatments.

Total western redcedar seedling weights in the 1.32- and 1.45-gram-density treatments were significantly heavier than those in the 1.59. Redcedar shoot and root weights in the 1.32-density treatment were also heavier than those in the 1.59-density treatment.

^{6/}Flocker, W. J., and Nielsen, D. R. Relationship between soil moisture and airspace associated with levels of bulk density that influence growth of tomatoes. Seventh Int. Congr. Soil Sci. Trans. (1960)1: 347-353. 1961.

^{7/}1.6 g. Ca(NO₃)₂, 1.0 g. KNO₃, 0.5 g. MgSO₄, and 0.3 g. KH₂PO₄ per liter H₂O.

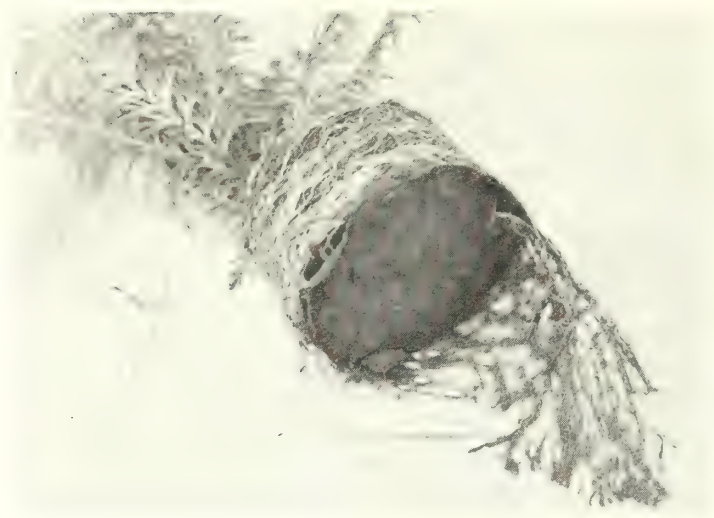


Figure 2.--Western redcedar roots did not penetrate a soil density of 1.59 grams per cubic centimeter. Note root growth around the edge of the compacted soil core, absence of roots in the core itself (which has been almost entirely removed), and the concentration of roots in the loose upper soil layer.

As the root depths recorded in table 1 indicate, the roots of all seven species grew through the 1.32-density soil cores all the way to the pot bottoms. The roots of western redcedar, Sitka spruce, and western hemlock did not penetrate 1.45-density cores, but roots of red alder, lodgepole pine, and Douglas-fir grew entirely through them. No roots penetrated the 1.59-density cores. The maximum root depths recorded in table 1 resulted from root growth between soil cores and pot walls in the 1.59-density treatment.

DISCUSSION

Plastic pots and soil cores expanded and contracted differently, producing a narrow space between each soil core and pot wall. This space should be

considered when the data listed in table 1 are interpreted.

Roots near the pot walls were able to grow down the space between pot wall and soil core (fig. 2). Nutrient solution added periodically during the growing season probably flowed through this space faster than it flowed through the soil core itself, and roots growing in this space may have received more nutrients than roots growing within the core.

If the above hypothesis is correct, the total seedling weights, shoot weights, root weights, and maximum root depths listed in table 1 were influenced by differences in nutrient availability. They should not be relied upon to compare species growth in high soil densities. We are left with the root depths within compacted soil cores.

Table 1.--Average weights and root depths of seedlings grown in three soil densities, by species, with standard errors (sandy loam, artificially compacted soil, in greenhouse)

Soil density ^{1/} and species	Total weight	Shoot weight	Root weight	Maximum ^{2/} root depth	Root depth within soil core
-----Gm.-----Cm.-----					
1.32 density:					
Red alder	97.28 (±6.18)	38.46 (±1.64)	58.82 (±6.74)	36.0 (±0)	36.0 (±0)
Western redcedar	23.94 (±1.18)	12.98 (±.69)	10.95 (±.52)	36.0 (±0)	36.0 (±0)
Lodgepole pine	12.50 (±1.18)	6.18 (±.89)	6.32 (±.41)	36.0 (±0)	36.0 (±0)
Douglas-fir	11.65 (±1.18)	6.17 (±.68)	5.48 (±.52)	36.0 (±0)	36.0 (±0)
Sitka spruce	5.36 (±2.04)	3.21 (±1.18)	2.15 (±.88)	36.0 (±0)	36.0 (±0)
Pacific silver fir	1.50 (±.26)	.77 (±.18)	.71 (±.10)	36.0 (±0)	36.0 (±0)
Western hemlock	.72 (±.08)	.42 (±.07)	.30 (±.04)	35.7 (±.3)	26.0 (±10.0)
1.45 density:					
Red alder	72.72 (±2.40)	27.17 (±3.18)	45.54 (±.97)	31.3 (±4.7)	31.3 (±4.7)
Western redcedar	20.45 (±1.54)	10.82 (±.59)	9.63 (±1.82)	36.0 (±0)	6.0 (±0)
Lodgepole pine	16.37 (±1.39)	6.83 (±.43)	9.54 (±1.09)	36.0 (±0)	36.0 (±0)
Douglas-fir	8.33 (±1.03)	3.50 (±.41)	4.83 (±.65)	36.0 (±0)	36.0 (±0)
Sitka spruce	6.17 (±.79)	3.53 (±.38)	2.64 (±.41)	36.0 (±0)	6.0 (±0)
Pacific silver fir	1.39 (±.12)	.74 (±.12)	.65 (±.01)	16.0 (±4.9)	9.7 (±3.7)
Western hemlock	3.21 (±.74)	1.96 (±.57)	1.25 (±.20)	14.3 (±2.3)	6.0 (±0)
1.59 density:					
Red alder	78.02 (±4.44)	34.11 (±2.88)	43.91 (±2.38)	36.0 (±0)	6.0 (±0)
Western redcedar	14.26 (±.41)	8.15 (±.38)	6.11 (±.10)	16.3 (±3.7)	6.0 (±0)
Lodgepole pine	9.44 (±1.14)	4.12 (±.48)	5.32 (±.65)	29.3 (±6.7)	6.0 (±0)
Douglas-fir	5.78 (±.70)	2.58 (±.27)	3.19 (±.44)	26.3 (±4.9)	6.0 (±0)
Sitka spruce	11.23 (±1.85)	6.77 (±1.15)	4.46 (±.73)	26.3 (±4.9)	6.0 (±0)
Pacific silver fir	1.57 (±.35)	.86 (±.25)	.71 (±.05)	12.7 (±2.3)	6.0 (±0)
Western hemlock	1.80 (±.56)	.70 (±.17)	1.10 (±.39)	13.3 (±1.8)	6.0 (±0)

^{1/}In grams per cubic centimeter.

^{2/}Includes roots growing between soil core and pot wall.

Root depths within compacted soil cores clearly indicate that the roots of some species are able to grow in moderately high soil densities where the roots of other species cannot grow. Absolute soil densities that are associated with measured root growth in greenhouse pots may or may not be associated with the same root growth in the field, even if soils of similar texture are compared--climatic conditions in greenhouse and field are different. The absolute soil density values listed here therefore are not useful in themselves. However,

relative differences between the root growth of different species in the same high density soil are useful--these relative differences should be applicable in the field regardless of the absolute soil densities or textures involved.

Lodgepole pine, Douglas-fir, and red alder roots can grow in soil densities that prohibit the growth of Sitka spruce, western hemlock, and western redcedar roots. Pacific silver fir ranks between the above species groups in respect to root penetration of high soil densities.

PNW-113

January 1970

SOME EFFECTS OF SHADE COVER ON STREAM
TEMPERATURE IN SOUTHEAST ALASKA

by

William R. Meehan, *Research Fisheries Biologist*



ABSTRACT

Water temperatures were recorded in several southeast Alaska streams with a portable thermometer accurate to 0.01° C. Measurements were made at 20-yard intervals in shaded and unshaded reaches and on cloudy and clear days. Results indicate that (1) the effects of streamside cover on stream temperatures can be evaluated by this technique, and (2) shade-producing streamside cover is important in maintaining cool water.

INTRODUCTION

Clearcut logging of watersheds in southeast Alaska frequently includes removal of streamside timber. The effect of such removal on the suitability of southeast Alaskan streams as fish habitat is largely unknown, although studies in other parts of the United States have demonstrated that increased water temperatures often result. A similar determination under the climatic conditions of southeast Alaska would greatly facilitate decisions about the harvest of timber along salmon streams. Many of the small streams in southeast Alaska maintain substantial runs of salmon, especially pink salmon (*Oncorhynchus gorbuscha* (Walbaum)). In total, these small streams produce a significant percentage of the salmon pack for southeast Alaska. On the watersheds of many of these small streams much of Alaska's timber resources are found.

Eschner and Larmoyeux^{1/} found that the average maximum stream temperature in a clearcut watershed in West Virginia was 8° F. higher than the control stream in an uncut watershed during the growing season and that, during the dormant season, the average minimum stream temperature was 3.5° F. lower in the clearcut watershed. Unpublished data from the USDA Forest Service, Pacific Southwest Forest and Range Experiment Station,^{2/} show that stream temperatures in a cleared canyon in California were as much as 15° F. higher than those in a similar but uncleared canyon. Brown and Krygier^{3/} indicated increases in stream temperature of up to 14° F. during warm summer periods in a clearcut watershed in Oregon. However, a recent paper^{4/} reported a maximum increase in summer stream temperatures of only 9° F. after clearcutting in two watersheds near Hollis on Prince of Wales Island, Alaska. The cool, mostly overcast climate of southeast Alaska is probably the main reason for this relatively small change in stream temperature after logging. These studies reported the effects on stream temperature of clearcutting all or parts of the watershed.

Brown and Krygier also stated that streams with small flow volumes are affected sooner and to a greater extent by changes in air temperature and solar radiation than larger streams and rivers. Levno and Rothacher^{5/} reported that exposing a large proportion of an Oregon streambed to solar radiation increased maximum stream temperatures and that excessive increases could be prevented by retaining streamside vegetation. Brown and Krygier (footnote 3) reported that removing streamside vegetation increased the mean monthly maximum temperature

^{1/} Eschner, Arthur R., and Larmoyeux, Jack. Logging and trout: Four experimental forest practices and their effect on water quality. *Progr. Fish-Cult.* 25: 59-67. 1963.

^{2/} Semiannual report of USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, for April-September 1959.

^{3/} Brown, George W., and Krygier, James T. Changing water temperatures in small mountain streams. *J. Soil & Water Conserv.* 22(6): 242-244. 1967.

^{4/} Meehan, W. R., Farr, W. A., Bishop, D. M., and Patric, J. H. Some effects of clearcutting on salmon habitat of two southeast Alaska streams. *Inst. Northern Forest., Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PNW-82*, 45 pp., illus. 1969.

^{5/} Levno, Al, and Rothacher, Jack. Increases in maximum stream temperatures after logging in old-growth Douglas-fir watersheds. *USDA Forest Serv. Pacific Northwest Forest & Range Exp. Sta. Res. Note PNW-65*, 12 pp., illus. 1967.

14° F. on a clearcut watershed in Oregon's Alsea River basin. They also marked a mass of water with fluorescent dye (under clear skies near midday) and noted that its temperature increased 16° F. in 1 hour as it passed through a reach of stream where clearcutting had removed shade-producing vegetation and exposed the streambed to direct sunlight. The cooling effects of streamside vegetation on stream temperatures were observed by Green,^{6/} who reported a decrease of 12° F. as a stream in North Carolina meandered 400 feet through forest and brush cover.

These scattered studies indicate that under various conditions, and in different areas of the United States, streamside vegetation is significant in determining the temperature regimen of a stream. In my study, I wished to determine the role of streamside vegetation under the cool, moist conditions of southeast Alaska. The study objectives were (1) to develop a practical method for measuring the effects of shade on stream temperature, and (2) to conduct exploratory studies of the relations between stream cover and water temperature.

STUDY LOCATION AND METHODS

The studies were conducted in small streams in the northern part of southeast Alaska, near the towns of Wrangell, Petersburg, Juneau, and Haines (fig. 1, table 1). Some sections of the streams were in unshaded clearcut or naturally open areas, and other sections were shaded by streamside vegetation. Thus, the effects of solar radiation as well as cover could be observed in the same stream. Water temperatures were measured under two sky conditions: (1) clear, sunny days and (2) completely overcast days (table 1). Most measurements under both conditions were made near midday between 1000 and 1400 hours.

The basic technique was to measure precisely the differences in water temperature over short reaches of stream and to relate these differences to shade and cloud cover. Measurements were made at 20-yard intervals along the streams, in shaded and unshaded reaches, with a portable resistance thermometer which measured temperatures to the nearest 0.01° C. After the concluding measurement of a series of observations, the temperature at the starting point was remeasured to determine the change during the sampling time interval. This change factor was then used to adjust each reading so that the effect of such change was minimal. For better evaluation of results, the temperature ranges encountered on each stream have been noted in tables 2 and 3.

^{6/} Green, G. E. Land use and trout streams. J. Soil & Water Conserv. 5(3): 125-126. 1950.

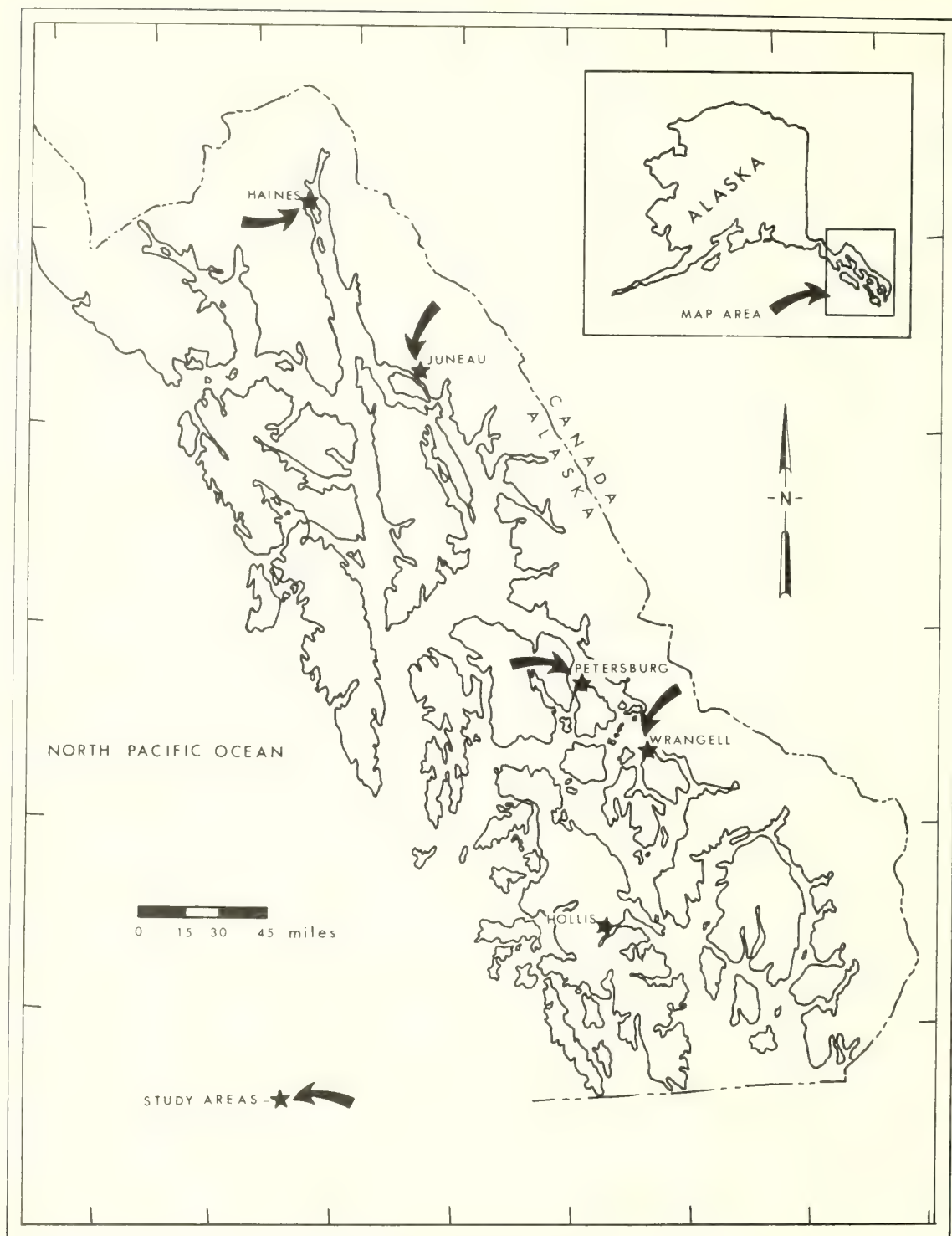


Figure 1.--*Southeast Alaska, showing location of study areas.*

Table 1.--Date and cloud cover at time temperatures were recorded
in several streams in southeast Alaska, 1967

Area and stream ^{1/}	Date	Cloud cover
- - Percent - -		
Haines:		
"Temperature" Creek	Aug. 3	0
	Oct. 13	100
Big Boulder Creek	Aug. 3	0
	Oct. 13	100
"Clear" Creek No. 1	Aug. 3	0
"Clear" Creek No. 2	Aug. 3	0
Juneau:		
Sweitzer Creek	July 24	0
Montana Creek	July 25	0
Petersburg:		
Twin Creek	Aug. 16	0
	Oct. 22	100
Falls Creek	Aug. 17	0
	Oct. 22	100
Ohmer Creek	Aug. 16	0
	Oct. 22	100
Ohmer Creek tributary	Aug. 16	0
	Oct. 22	100
Blind River tributary	Aug. 16	0
	Oct. 22	100
"Foam" Creek	Aug. 17	0
	Oct. 22	100
Wrangell:		
Pat's Creek	Aug. 15	0

^{1/} Creek names enclosed in quotation marks are unofficial names adopted for use in the study.

Table 2.--Average temperature difference per 20 yards of streams on clear days with and without shade-producing cover, in selected areas of southeast Alaska, 1967

Area and stream ^{1/}	Temperature range in stream length measured	Length of stream measured		Average temperature difference per 20 yards	
		Open	Shaded	Open	Shaded
	<i>Degree C.</i>	<i>-----Yards-----</i>		<i>-----Degree C.-----</i>	
Haines:					
"Temperature" Creek	10.37-11.77	620	60	+0.07	-0.05
Big Boulder Creek	12.59-12.85	360	80	+0.02	-.09
"Clear" Creek No. 1	<u>2/</u> 4.30- 5.39	280	340	<u>2/</u> +0.11	<u>2/</u> -.07
"Clear" Creek No. 2	<u>2/</u> 5.81- 6.33	380	400	<u>2/</u> +0.05	<u>2/</u> -.03
Juneau:					
Sweitzer Creek	8.23- 8.49	60	--	+0.09	--
Montana Creek	7.19- 8.67	240	60	+0.07	-.09
Petersburg:					
Twin Creek	10.40-11.09	100	40	+0.21	-.18
Falls Creek	13.70-13.94	40	60	+0.13	-.03
Ohmer Creek	13.06-13.40	80	120	+0.14	-.15
Ohmer Creek tributary	11.43-11.77	40	40	+0.21	-.18
Blind River tributary	11.70-12.13	100	140	+0.15	-.07
"Foam" Creek	12.00-13.61	120	60	+0.19	-.11
Wrangell:					
Pat's Creek	13.82-16.01	380	220	+0.14	-.08

^{1/} Creek names enclosed in quotation marks are unofficial names adopted for use in the study

^{2/} Observed value; temperature at first station not checked at end of series.

Table 3.--Average temperature difference per 20 yards of streams on overcast days,
near Haines and Petersburg, Alaska, 1967

Area and stream ^{1/}	Temperature range in stream length measured	Length of stream measured	Average temperature difference per 20 yards
	<i>Degree C.</i>	<i>Yards</i>	<i>Degree C.</i>
Haines:			
"Temperature" Creek	4.71-5.11	300	+0.01
Big Boulder Creek	5.02-5.07	240	0
Petersburg:			
Twin Creek	5.57-5.59	120	0
Falls Creek	6.09-6.17	240	+0.01
Ohmer Creek	6.03-6.12	220	+0.01
Ohmer Creek tributary	5.61-5.65	140	+0.01
Blind River tributary	6.42-6.45	120	0
"Foam" Creek	6.25-6.32	140	+0.01

^{1/} Creek names enclosed in quotation marks are unofficial names adopted for use in the study.

RESULTS

The greatest range in temperature observed within any one stream was 2.30° C., within 600 yards in Pat's Creek in the Wrangell area. A temperature check at the starting point after all measurements were recorded showed that the stream had actually warmed 0.22° C. during the sampling interval, so that the extreme range of temperature increase was actually closer to 2.08° C; this temperature range was recorded on a clear, sunny day. The greatest range in temperature observed on an overcast day was 0.40° C. in "Temperature" Creek in the Haines area in 300 yards. This range is considerably higher than those of other streams in both areas measured under cloudy skies, because a slightly warmer tributary affected the main stream. The temperature range before this tributary was reached was 0.18° C. in 240 yards of measurements.

Temperature measurements at 20-yard intervals (tables 2 and 4) show that on clear summer days, shade-producing streamside vegetation plays a definite role in cooling or maintaining coolness of the study streams. The data also suggest that average temperature differences

Table 4.--Summary of mean temperature differences under various sky and cover conditions for streams in selected areas of southeast Alaska, 1967

Area and treatment	Number of temperature measurements taken	Average temperature difference
		<i>Degree C.</i>
Haines-Juneau:		
Clear-open	28	+0.071
Clear-shaded	12	-.060
Cloudy ^{1/}	27	+.011
Petersburg-Wrangell:		
Clear-open	38	+.164
Clear-shaded	31	-.081
Cloudy ^{2/}	49	+.009

^{1/} Haines only.

^{2/} Petersburg only.

per 20 yards in open reaches of stream on clear days were greater in Petersburg-Wrangell streams than in Haines-Juneau area streams. Analysis of variance showed the difference was significant ($F = 16.52$). No significant difference was found between the two areas under clear-shaded and cloudy weather conditions.

DISCUSSION

In southeast Alaska, water temperature in small streams is most affected by the presence or absence of shade-producing streamside vegetation on clear, sunny, midsummer days. Under these conditions solar radiation has its maximum effect.

This exploratory study shows that streamside vegetation is important in maintaining cool streams, particularly during the warm, clear weather that occurs at times between May and September in southeast Alaska. On overcast days, the effects are less pronounced. No explanation is suggested here for the significant difference between average stream temperature increases in the Haines-Juneau and Petersburg-Wrangell areas under clear, unshaded conditions. The range of temperatures measured was quite similar in streams of both areas. Relative humidity, soil temperature, and ground water addition all may have been influencing factors.

The results of the study conducted at Hollis (see footnote 4) should be considered in the light of the present findings. There, a maximum increase in stream temperature of 9° F. occurred during the summer months after the watersheds were clearcut. Hollis is typical of much of southeast Alaska in terms of weather, and field observations there from May through September for 3 years indicate that about 35 days of partly cloudy to clear skies can be expected during this 5-month period. It is quite likely that average stream temperatures in other areas with similar generally overcast weather conditions would be affected similarly by timber harvest. However, if the shade-producing canopy were allowed to remain, the daily variations in temperature would probably be smaller.

Probably the most important element in the effect of streamside vegetation on water temperature in southeast Alaska is the biological significance of increased temperatures. The results of this study and that near Hollis (see footnote 4) indicate that temperature increases after clearcutting in this region do not approach lethal limits for fish populations. However, the indirect effects of temperature increases on the environment, particularly in the case of resident fish populations, are not known. Some rise in temperature might increase the primary productivity of the stream, perhaps enhancing the feeding opportunities and growth of resident fish. Winter temperatures should likewise be considered; winter stream temperature differences resulting from streamside cover removal could have greater effects on fish populations in southeast Alaska than summer temperature increases. Warmer daytime water temperatures in winter could be beneficial; colder nighttime temperatures could be harmful. The total effect should be determined.

The results of this study indicate that further research is necessary. Measurements of solar radiation should be made concurrently with temperature. The roles of relative humidity, ground water addition to the stream, soil temperature, and thermal exchange by convection should be considered. In other words, the "micrometeorology" of the stream and its immediate surroundings should be more thoroughly investigated.

When the precise role of streamside vegetation in the aquatic environment is known, fisheries and land managers will be better able to prescribe clearcutting patterns that effect an optimum relationship between timber and salmon production.

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PNW-114

January 1970

SOIL MOISTURE TRENDS UNDER THREE DIFFERENT COVER CONDITIONS

by

H. G. Herring, *Hydrologist*



ABSTRACT

After a 3-year study of summer soil moisture trends in a grassy opening, a second-growth ponderosa pine stand, and a clearcut plot in the pine stand, we concluded: (1) there was relatively little difference in soil moisture regimes between the natural cover types; (2) the difference between the moisture regime of the cut plot and those of both the natural cover types was highly significant; (3) antecedent winter precipitation has a strong differential effect on the summer soil moisture regimes of the three cover types. In terms of autumnal soil moisture savings, if we assume the pine-to-clearcut plot conversion to equal 100 percent of attainable savings, the grass is only 20 percent as effective. The absolute value of moisture savings is highly dependent upon the weather.

A knowledge of soil moisture variations as influenced by differing cover conditions is necessary for a land manager whose objectives include watershed management. For example, the vegetative cover on a given piece of land will influence the soil moisture on that land through the processes of interception, transpiration, shading, and wind modification.

During the years 1963 through 1965, some soil moisture data were gathered that add to our knowledge. The purpose of this note is to report these data, point out the apparent moisture differences between cover conditions, and discuss some of the possible causes for these differences.

STUDY AREA

The study was conducted in central Washington on the Mission Creek drainage of the Wenatchee National Forest, about 6 miles WSW. of Wenatchee at latitude 47°23' N., longitude 120°26' W. The elevation is 3,200 feet, near the top of a southeast-oriented ridge. The slope varies from 5 to 20 percent, and aspects range from ESE. to SW.

The general type classification of the area is ponderosa pine, but timbered patches alternate with natural openings. The timber has a moderate understory of elk sedge (*Carex geyeri*), arrowleaf balsamroot (*Balsamorhiza sagittata*), lupine (*Lupinus* spp.), and some antelope bitterbrush (*Purshia tridentata*). The open areas are vegetated principally with cheatgrass brome (*Bromus tectorum*), lupine, balsamroot, and scattered bitterbrush. The timber in the study area is a second-growth ponderosa pine (*Pinus ponderosa*) stand with a mean basal area of 195 square feet per acre. The stand averages 1,275 stems per acre with a mean diameter of 5.3 inches.

Soils are relatively deep, well-drained sandy loams, derived from sandstone. Field capacity (0.1 atmosphere tension) is 29 percent by volume or about 3.5 inches per foot. Wilting point, as determined by the 15 atmospheres tension, is 8.7 percent by volume or just over 1 inch per foot.

Climate is characterized by warm, dry summers and relatively cold winters. The bulk of the precipitation, which totals about 18 inches per year, occurs as snow.

The area was cut over early in this century and heavily grazed by sheep in the 1920's and 1930's. Domestic animals have been excluded since 1954, but the area is used by a large deer herd and some elk.

PROCEDURE

In July 1962, 16 soil moisture access tubes were installed, all within 200 yards of each other. Most tubes were installed to a depth of 9 feet, but rock forced us to terminate some at shallower depths. The shortest tube extended to 66 inches. Six tubes were in a natural opening, eight were in a ponderosa pine stand, and two were located in a 40- by 40-foot plot in the pine, clearcut just prior to installation of the access tubes (figs. 1 and 2).

These tubes were allowed to equilibrate until May 1963, when measurements were started. The measurements were made with a 5-millicurie radium-beryllium neutron probe and scaler for 1 minute at every 6 inches for the first 2 feet and every foot thereafter. Measurements were scheduled approximately every 2 weeks from snow disappearance until the fall storms terminated the dry season. Measurements were made from



Figure 1.--Soil moisture being measured in a grass cover type, Mission Creek drainage, Wenatchee National Forest, July 1962.



Figure 2.--Soil moisture access tubes installed in a clearcut plot, Mission Creek drainage, Wenatchee National Forest, July 1962. A ponderosa pine stand is just beyond.

May 21 to August 21, 1963; May 4 to September 20, 1964; and April 28 to September 14, 1965. In none of these years was the measurement started as soon as would have been desirable because of the delayed snowmelt on the access road. In the first year also, equipment failure forced a delayed start and premature end to the season's measurements.

Surface moisture was not measured. Our reasoning was that the soils near the surface will quickly dry to wilting point regardless of the vegetation. Neutron counts were made at 6-inch depths to verify this assumption but not used in the analyses; therefore, all data given refer to the soil profile below the 9-inch depth.

Concurrent with soil moisture determinations, two nonrecording precipitation gages were installed and maintained.

RESULTS AND DISCUSSION

For analysis, the individual depth measurements were grouped: 9-21 inches, 21-42 inches, and 42-78 inches. These groupings coincided as much as possible with apparent differences in root concentrations. Weighted mean moisture content in inches per foot was computed for each class and the results plotted (fig. 3). Total precipitation during each intermeasurement period is also shown. During the fall of 1963, vandals pulled the tubes in the clearcut plot partially out of the ground. We were unable to force the tubes to the original depth, which accounts for the missing data below 42 inches in 1964. In the fall of 1964, the holes were augered to the original depth and the access tubes reinstalled.

When the differences in moisture content between cover types were computed (fig. 4), there was relatively little difference between the natural openings and the pine, especially above 42 inches. At the shallower depths, the slight differences that did exist were inconsistent. In comparison, the soil moisture content of the clearcut plot was considerably greater than that of the other cover types.

Moisture depletions during the measurement period each year were computed for each of the depth horizons and for the entire 9- to 78-inch profile (table 1). The clearcut pine would appear to have used more moisture than either of the other two cover conditions, at least for 1964 and 1965; but if we look back to figure 3, we can see that such a conclusion would probably be invalid. The clearcut plots appeared to lose more moisture during the measurement period only because measurements were started at a time when this plot contained more moisture than did the two natural conditions. As pointed out previously, the field capacity for these soils is about $3\frac{1}{2}$ inches per foot; and at the time of the initial measurement each year, the soils of the meadow and the ponderosa pine stand had already dried to well below field capacity. The soils in the clearcut plot, however, were still quite close to field capacity.

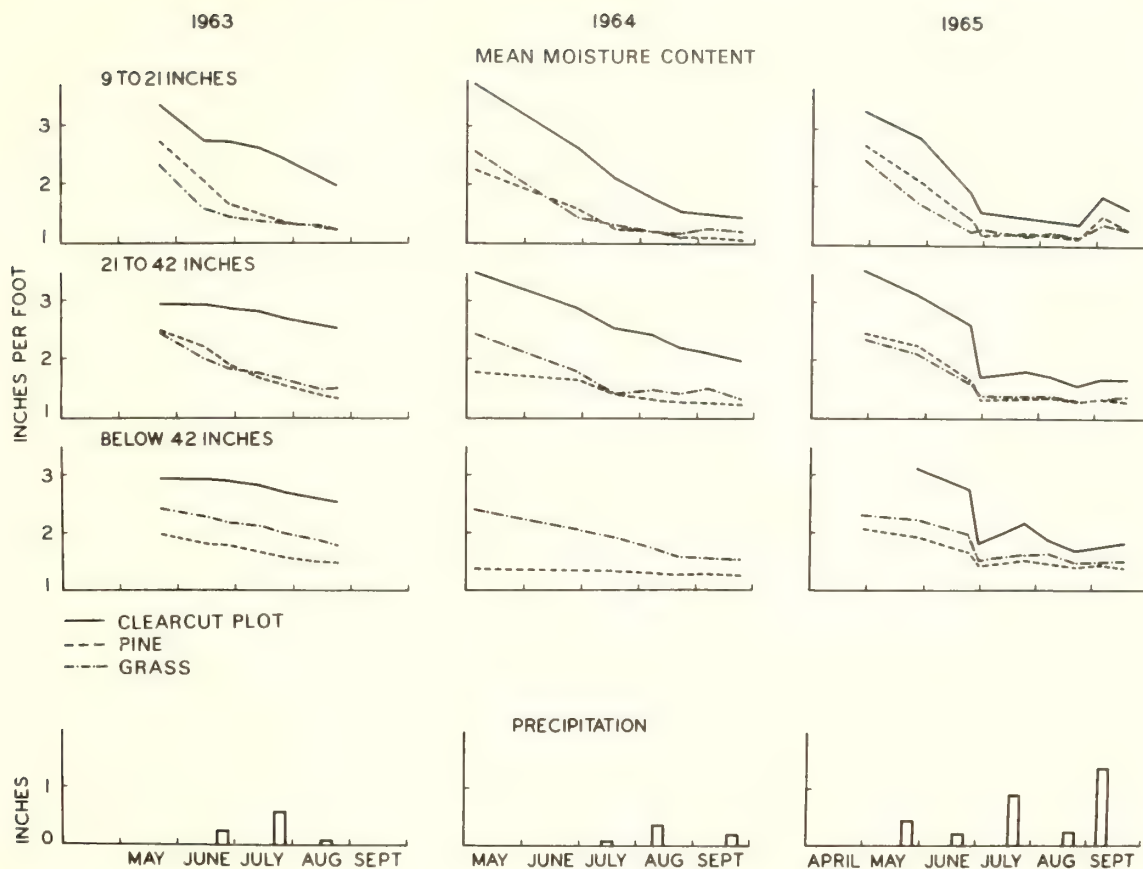


Figure 3.--Soil moisture trends showing moisture depletion for three depth zones and three vegetative cover conditions; study on Mission Creek drainage, Wenatchee National Forest, 1963-65.

There are several reasons for this initial moisture difference. As soon as transpiration starts in the spring, those areas containing a complete stand of the natural vegetation will begin to dry out quite rapidly. A small clearcut plot, however, with only a light cover of understory vegetation remaining, will not lose soil moisture as rapidly. Another contributing factor in the initially higher soil moisture content of the clearcut plot is the increased snow accumulation in this relatively small opening and a consequentially prolonged melting period in contrast to the natural conditions. Finally, in some years, there may be a lack of complete recharge of the ponderosa pine and grassland soils. Figure 3 indicates that these soils reached a somewhat lower level of soil moisture each fall than did the soil in the clearcut plots.

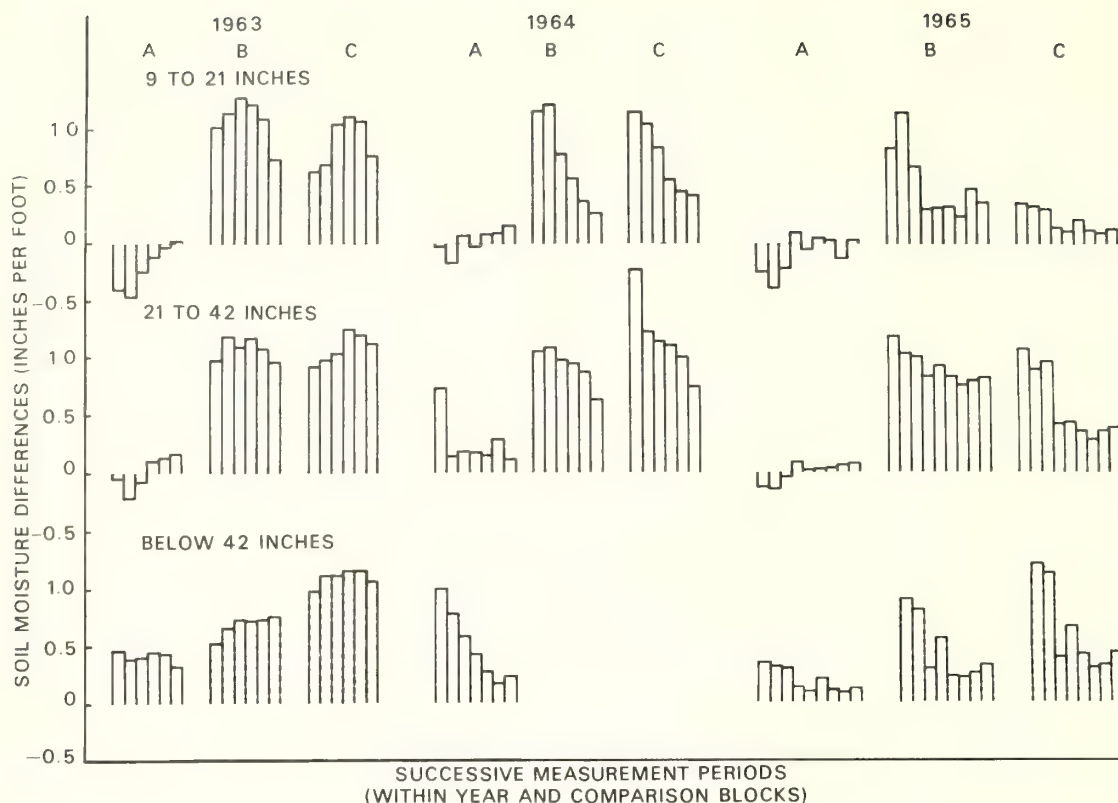


Figure 4.--Moisture differences by cover, depth, year, and relative date; study on Mission Creek drainage, Wenatchee National Forest, 1963-65. (The bars within each block are in chronologic sequence and represent the following differences: A, grass minus pine; B, cut plot minus grass; C, cut plot minus pine.)

There was an anomalously low soil moisture depletion under ponderosa pine in 1964 (table 1). Again, we can explain this by referring back to figure 3. At the 21- to 42-inch depth, and especially below 42 inches, the ponderosa pine showed very little use of soil moisture throughout the measurement period, because at both of these depths, soil moisture at start of the season was quite low. Upon checking the records for the winter of 1963-64, we found that the weather was extremely dry. The Wenatchee weather station reported 73 percent of normal precipitation during the period October 1963 through March 1964. With this abnormally low winter precipitation and the interception by the ponderosa pine canopy, we apparently failed to achieve complete recharge at the 21- to 42-inch depth and almost no recharge below 42 inches. These results are similar to those reported by Orr^{1/} for the Black Hills.

^{1/} Orr, Howard K. Soil moisture trends after thinning and clearcutting in a second-growth ponderosa pine stand in the Black Hills. Rocky Mountain Forest and Range Exp. Sta. USDA Forest Serv. Res. Note RM-99, 8 pp., illus. 1968.

Table 1.--*Soil moisture depletion at varying depths during measurement period;
study on Mission Creek drainage, Wenatchee National Forest*

Measurement period and type of cover	Depth (inches)			Weighted mean, 9 to 78 inches	Total, 9- to 78-inch profile
	9-21	21-42	42-78		
- - - - - Inches per foot - - - - - Inches					
1963:					
Grass	1.09	0.94	0.64	0.81	4.66
Ponderosa pine	1.51	1.15	.50	.87	5.02
Clearcut pine	1.38	.97	.42	.75	4.34
1964:					
Grass	1.38	1.11	.87	1.03	5.93
Ponderosa pine	1.54	.50	.12	.48	2.78
Clearcut pine	2.28	1.53	<u>1</u> /.86	1.31	7.54
1965:					
Grass	1.21	1.01	.89	.98	5.65
Ponderosa pine	1.46	1.20	.66	.96	5.54
Clearcut pine	1.68	1.89	1.32	1.56	8.95

1/ Estimated from partial measurements.

Looking at figure 3, we detect the influence of the deeper rooting depths of the ponderosa pine. Down to 42 inches there was very little difference in soil moisture depletion rates between the grassy opening and the ponderosa pine stand; but below 42 inches, the pine soils reached somewhat lower moisture levels than did the soils in the opening.

The differences in autumnal soil moisture content of the 9- to 78-inch profile under the three cover conditions were as follows:

	<u>1963</u>	<u>1965</u>
	--(Inches per foot)--	
Grass minus pine	0.21	0.08
Clearcut plot minus grass	.82	.32
Clearcut plot minus pine	1.02	.40

In theory, these differences are the potential gains in available water as we change from one condition to another. It is interesting to note that, in both years for which we have complete data, if we assume a two-step conversion from pine to grass, i.e. pine to cut plot followed by cut plot to grass, the values for autumnal deficits show an algebraic balance. In 1963, for example, converting from pine to a cut plot resulted in 1.02 inches per foot-depth in water savings. Of this, we would lose 0.82 inch per foot in converting the clearcut plot to grass, resulting in a net savings of 0.20 inch. This compares very favorably with the 0.21-inch measured difference between the pine and the grass. If we carry out the same calculations for 1965, the balance is exact.

There are two conclusions that can be drawn from this study:

1. The grassy openings and ponderosa pine stand existing on the study area show very similar soil moisture regimes except during years of abnormally low winter precipitation and for soils deeper than average for the ponderosa pine zone of north-central Washington. Other studies are necessary to define the geographic limits of this relationship.
2. Removing ponderosa pine results in a significant initial alteration of the soil moisture regime and a higher soil moisture content at the end of the growing season. Additional research is needed to determine how long this effect will last.

* * * * *

PNW-115

January 1970

SEEDLING GROWTH OF EIGHT NORTHWESTERN TREE SPECIES
OVER THREE WATER TABLES

by

Don Minore, *Plant Ecologist*



ABSTRACT

Seedlings of eight northwestern tree species were grown over controlled water table depths of 7.5, 35.5, and 66.0 centimeters. Lodgepole pine, western redcedar, red alder, and Sitka spruce were all tolerant of shallow water tables. However, lodgepole pine and western redcedar grew best over the deepest water table, as did western white pine. Douglas-fir was intolerant of shallow water tables. Western hemlock and Pacific silver fir were not significantly affected by depth of the water table.

INTRODUCTION

Selecting the best tree species for a forest site is essential for full production, but basic data on species and site are scarce. Furthermore, many of the existing data are difficult to compare--individual species often are studied under different experimental conditions, and site quality is influenced by many environmental factors that affect different species differently. For example, some species cannot grow in areas where water tables are near the surface, while others seem to grow well in such areas.

Stephens^{1/} found lodgepole pines growing in marshes where water tables were at the surface during much of the year. Godman^{2/} concluded that water table levels affect the growth of yellow birch, and Phillips and Markley^{3/} related water table depths to the site index of sweetgum. However, these authors did not compare species. McClurkin^{4/} compared the growth and phenology on shallow water table sites of baldcypress, white ash, and sweetgum after thinning. But, because the water table depth was different for each of these three species, comparison of species growth over shallow water tables is difficult.

Mueller-Dombois^{5/ 6/} compared the growth of jack pine, red pine, black spruce, and white spruce over controlled water tables in a greenhouse. He used artificial slopes to produce water table depth gradients, and the four species were planted along these gradients. Lateral root growth upslope from shallow portions of the gradients produced minor inconsistencies in Mueller-Dombois' data, but he determined an optimum water table depth for seedlings of each species. This optimum depth differed with soil texture.

Controlled water table depths and uniform soil texture were used in the present study to compare the effects of water table depth on seedling growth of eight northwestern species: Douglas-fir, Sitka spruce, western hemlock, western redcedar, red alder, lodgepole pine, western white pine, and Pacific silver fir.

^{1/} Stephens, F. R. Lodgepole pine--soil relations in the north-west Oregon Cascade Mountains. J. Forest. 64: 184-186, illus. 1966.

^{2/} Godman, R. M. Are water table levels an important factor in the establishment and growth of yellow birch? Papers Mich. Acad. Sci., Arts and Letters 44: 183-190. 1959.

^{3/} Phillips, John J., and Markley, Marco L. Site index of New Jersey sweetgum stands related to soil and water-table characteristics. Northeastern Forest Exp. Sta. USDA Forest Serv. Res. Pap. NE-6, 25 pp., illus. 1963.

^{4/} McClurkin, D. C. Diameter growth and phenology of trees on sites with high water tables. Southern Forest Exp. Sta. USDA Forest Serv. Res. Note SO-22, 4 pp., illus. 1965.

^{5/} Mueller-Dombois, Dieter. Effect of depth to water table on height growth of tree seedlings in a greenhouse. Forest Sci. 10: 306-316, illus. 1964.

^{6/} Mueller-Dombois, D. Technique for studying soil-water-growth relations on an artificial slope. In Forest-soil relationships in North America. Corvallis: Oregon State University Press, pp. 153-161, illus. 1965.

MATERIALS AND METHODS

Plastic tiles were cemented to plastic sewer pipe to form cylindrical pots 76 centimeters in height and 10 centimeters in diameter. Small holes drilled in the sides of the pots made them water-permeable. The pots were placed in plastic refuse barrels (68.5 centimeters in height) through holes cut in the barrel covers. Eight pots were placed in each barrel (fig. 1). Pots then were loosely filled with blended sandy loam, and the refuse barrels were filled with water supplied from a gravity-flow water system connected to the barrels with plastic pipe and Tygon tubing.^{1/} A slow, continuous waterflow through the filled barrels was maintained by screw clamps on the tubing.



Figure 1.—Refuse barrel with soil-filled pots at beginning of study. Note Tygon tubing and screw clamp used to regulate waterflow.

Fifteen refuse barrels containing 120 pots were spaced 2 meters apart. Single drainage holes were made in the sides of 10 barrels--five at 35.5 centimeters and five at 66.0 centimeters below the soil surface in the pots. No drainage holes were made in the remaining

^{1/} Mention of a proprietary name does not imply endorsement or approval of the product by the U. S. Department of Agriculture to the exclusion of others which may also be suitable.

five barrels. Three artificial water table depths were thus established at 7.5, 35.5, and 66.0 centimeters below the soil surface. Each of the three depths was assigned at random to five refuse barrels. Species were also placed at random in each barrel, with one species in each of the eight pots. The refuse barrels were located in a level, open field at Cascade Head Experimental Forest near Otis, Oregon, at an elevation of 160 feet.

Seeds of all eight species were obtained from low-elevation, coastal seed sources. They were germinated in petri dishes and 15 were planted in each of the randomly assigned pots in each refuse barrel in May 1966. All drainage holes were plugged to provide abundant soil moisture during the summer, but most of the seedlings died in July and August. Lack of shade and surface drying of the dark, heat-absorbing soil surface may have been responsible for this loss. All seedlings were removed in the autumn, and the experiment was repeated in 1967.

Seeds were again planted at random in each refuse barrel in 1967, but this time 20 seeds of the same species were sown in each pot and covered with 1 centimeter of a fine-grade granite grit. The western white pine seeds were sown in January and allowed to stratify; the other seeds were sown in March. A wooden screen approximately 12 centimeters high was constructed along the southern edge of each pot to provide shade.

Germination began in April 1967. All drainage holes were again plugged to provide abundant soil moisture during the summer, and all first-season seedling growth occurred over the same shallow water table. First-year survival of all species was excellent.

In September the seedlings were thinned, leaving two seedlings in each pot. Drainage holes were unplugged during the first fall rains in October to establish water table depths of 7.5, 35.5, and 66.0 centimeters; these depths were maintained for the duration of the study. All pots^{8/} were fertilized three times with equal amounts of nutrient solution during the summer of 1968. A slow waterflow through the refuse barrels maintained constant water table depths, but none of the pots were watered from above. However, precipitation provided some surface water during the summer of 1968.

Surviving seedlings were counted in September 1968. Pots were then broken, and roots were carefully washed free of soil. The shoot and roots of the largest surviving seedling in each pot were oven-dried

^{8/} 1.6 g. $\text{Ca}(\text{NO}_3)_2$, 1.0 g. KNO_3 , 0.5 g. MgSO_4 , and 0.3 g. KH_2PO_4 per liter of water.

at 65° C. for 48 hours and weighed. The data were subjected to split-plot analyses of variance using the refuse barrels as main plots.

RESULTS

All Sitka spruce, western redcedar, lodgepole pine, and Pacific silver fir seedlings survived. All Douglas-fir seedlings also survived over water table depths of 35.5 and 66.0 centimeters, but 40 percent died over the 7.5-centimeter water table. Red alder survival was poorest over the deepest (66.0 centimeters) water table. There was no correlation between western hemlock and western white pine mortality and water table depth.

Inherent growth rate differences resulted in significant size and weight differences between species. Red alder was the fastest growing; western hemlock, Pacific silver fir, and western white pine were the slowest. These inherent differences, which were evident over all three water tables, are illustrated in figure 2.



Figure 2.—Seedlings at conclusion of study — 66.0-centimeter water table. Clockwise from left corner of numbered card, the species are: Sitka spruce, lodgepole pine, western white pine, red alder, western hemlock, Douglas-fir, and Pacific silver fir. Western redcedar occupies the center pot.

Average seedling weights are listed in table 1. The analyses of variance showed highly significant species differences and highly significant species-water table interactions. Alder seedlings were much heavier than seedlings of any other species over all three water tables; Pacific silver fir and western hemlock seedlings were noticeably lighter than seedlings of any other species. Weight differences and species-water table interactions are less evident for the other species. These differences and interactions are illustrated in figures 3-5. Red alder was omitted in figure 5 to permit large-scale illustration of the other species relationships on a single coordinate system.

Table 1.--Average shoot weight, root weight, and total weight of largest surviving seedling in each pot by water table depth and species

Species	Water table depth		
	7.5 centimeters	35.5 centimeters	66.0 centimeters

	----- Grams -----		
Shoot weight:			
Red alder	4.25	41.11	13.09
Western redcedar	.76	2.90	3.10
Lodgepole pine	1.32	2.45	3.25
Douglas-fir	.09	1.99	1.56
Sitka spruce	.37	1.77	1.38
Western white pine	.09	.49	.90
Pacific silver fir	.13	.27	.15
Western hemlock	.11	.08	.08
Root weight:			
Red alder	2.01	18.59	8.25
Western redcedar	.31	1.30	1.54
Lodgepole pine	.40	.92	1.13
Douglas-fir	.05	.75	.85
Sitka spruce	.22	.81	.62
Western white pine	.07	.39	.74
Pacific silver fir	.13	.22	.13
Western hemlock	.05	.06	.04
Total weight:			
Red alder	6.26	59.70	21.34
Western redcedar	1.07	4.20	4.64
Lodgepole pine	1.72	3.37	4.38
Douglas-fir	.14	2.74	2.41
Sitka spruce	.59	2.58	2.00
Western white pine	.16	.88	1.64
Pacific silver fir	.26	.49	.28
Western hemlock	.16	.14	.12



Figure 3.—Lodgepole pine seedlings at conclusion of study, grown over 7.5-centimeter (left), 35.5-centimeter (center), and 66.0-centimeter (right) water tables.



Figure 4.—Douglas-fir seedlings at conclusion of study, grown over 7.5-centimeter (left), 35.5-centimeter (center), and 66.0-centimeter (right) water tables.

Western hemlock and Pacific silver fir seedlings were not significantly affected by the different water table treatments. Slow growth rather than shallow water table tolerance probably was responsible; they grew very slowly on all three water tables. Therefore, these two species are not compared with the other species in figure 5. The shallow (7.5 centimeters) water table adversely affected all other species.

Red alder, Sitka spruce, and Douglas-fir seedling weights were heaviest over the 35.5-centimeter water table, but Douglas-fir root weights were heaviest over the 66.0-centimeter water table. Lodgepole pine, western redcedar, and western white pine seedlings were heaviest over the 66.0-centimeter depth.

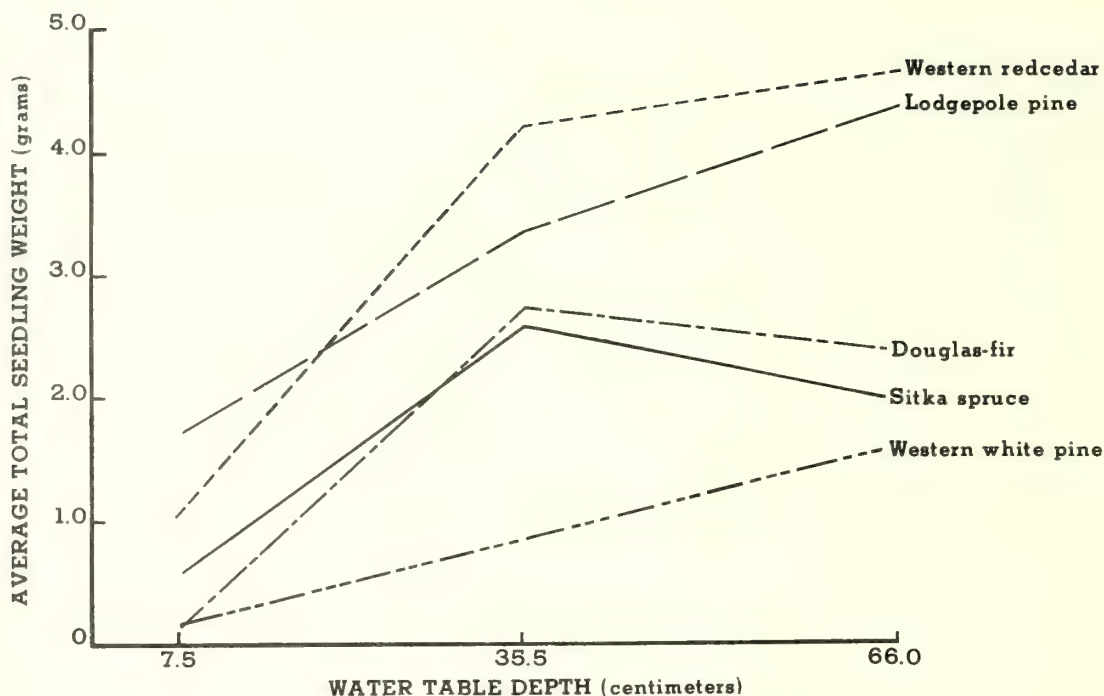


Figure 5.—Relationship of seedling weight to water table depth, by species.

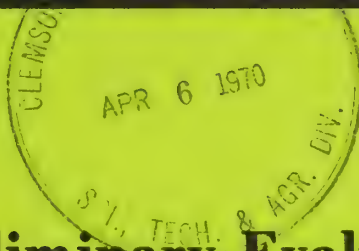
DISCUSSION

Data indicate that, although lodgepole pine and western redcedar are suitable species for shallow water table areas, they seem to grow best over deeper water tables. Red alder and Sitka spruce, also suitable for shallow water table areas, seem less suited to deep water tables. Douglas-fir is not tolerant of shallow water table depths and should not be planted where water tables are near the surface.

The artificial nature of this experiment should be emphasized. The absolute water table depth information presented here cannot be applied as such in the field. However, relative species relationships should be so applicable; red alder, Sitka spruce, lodgepole pine, and western redcedar seedlings should grow better than Douglas-fir seedlings over shallow water tables on coastal sites. Future field measurements and observations should make it possible to quantify these species relationships.

PNW-116

February 1970



A Preliminary Evaluation of the Hazards of 2,4,5-T in the Forest Environment

by

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Use Pesticides Safely
FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

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This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife -- if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

ABSTRACT

Increasing concern about the quality of man's environment has resulted in careful scrutiny of the use of 2,4,5-T for vegetation management. The hazard of using 2,4,5-T in the forest depends on the likelihood an organism will be exposed to a harmful dose.

Aerial applications of 2,4,5-T to forest lands result in an initial low-level, short-term stream contamination which does not represent a significant hazard to fish or animals. The extensive adsorption and degradation of 2,4,5-T in the forest floor prevent subsequent movement from treated areas to surface and ground waters. The primary exposure of animals to 2,4,5-T will be by ingestion of treated vegetation. Rainfall, growth dilution, and degradation markedly reduce herbicide residues in vegetation within a few weeks after application.

2,4,5-T is low in acute toxicity, does not persist for long periods in the soil or vegetation, and is rapidly excreted by animals. The hazard of 2,4,5-T in the forest environment is low when used according to tested procedures.

There is increasing concern about the quality of man's environment, particularly as it may be affected by the widespread use of chemicals. Pesticide chemicals used for crop production, vegetation management, and protection of the public health have received considerable attention. Concern about the impact of chemicals introduced into the environment is justified; we must avoid pollution which will jeopardize the well-being of man and his environment.

Forest managers must produce more wood fiber from less land to help sustain an increasing population. The demand for wood fiber requires intensification of forest management, including the use of chemical tools (Crafts 1967). But these chemicals must not be hazardous to man, and they must not endanger the quality of his environment.

The herbicide 2, 4, 5-trichlorophenoxyacetic acid (2, 4, 5-T) is a particularly effective tool for vegetation management on forest lands. It is used on powerline, railroad, and road rights-of-way, but its most important use is in connection with the establishment and release of conifers on forest land. For these purposes, 0.5 to 4 pounds of 2,4,5-T per acre are applied as low volatile esters dissolved or emulsified in diesel oil or water.

The safety of 2,4,5-T has recently been questioned. A preliminary study reported pregnant mice and rats fed repeated doses of 2,4,5-T butyl ester produced higher than expected numbers of malformed

offspring (Anonymous 1969; Nelson 1969). We feel the response of inbred strains of laboratory mice and rats to repeated relatively large doses of 2, 4, 5-T may have little bearing on the hazard of 2, 4, 5-T in normal forest use.

The hazard of a chemical to an organism is composed of two components. One is the likelihood the organism will be exposed to the chemical. The second is the inherent toxicity of the chemical to the organism. The hazard is small if either likelihood of exposure or toxicity of the chemical is low. To properly assess the hazard associated with the use of a particular chemical, we must consider both of these components.

The characteristic movement and persistence of a chemical in the environment is called its *behavior*. The behavior of 2, 4, 5-T in the environment will largely determine its residue levels in air, water, soil, and plants, and hence, the likelihood and level of exposure of man and animals.

The behavior of a chemical is a result of the interaction between the properties of the chemical and the environment. For instance, vaporization into the atmosphere will be governed by interaction of the chemical with treated surfaces and by the temperature of the environment. The susceptibility of 2, 4, 5-T to metabolism by plants and soil micro-organisms will determine its persistence in plants and soil. The water solubility and adsorption characteristics of a chemical govern its mobility in soil and, therefore, the degree of surface or ground water contamination. These are only a few of the factors which will regulate pesticide residue levels.

The behavior of 2, 4, 5-T in the forest environment of the Pacific Northwest has been studied (Tarrant and Norris 1967). Stream contamination is one of the first and most sensitive indicators of pollution of the forest environment. Norris (1967) monitored stream contamination from operational aerial applications of 2, 4, 5-T and other herbicides to Oregon forest lands and found:

1. Some herbicide appeared in nearly all streams which flowed through or by treated areas.
2. Maximum concentrations occurred during application immediately below the treated area and were a function of the amount of stream exposed to spray.

3. Herbicide residues were found in the stream for only a few hours after application in most instances.
4. Nearly all the herbicide found in the stream resulted from direct application to the water which can be avoided.

Concentrations of 2, 4, 5-T in streams never exceeded 0.1 part per million (p. p. m.) and did not exceed 0.01 p. p. m. for more than 1 day after treatment close to the spray unit. These levels are not acutely toxic to fish or animals. Rapid dilution with downstream movement reduced concentrations of 2, 4, 5-T below the minimum detectable limit of 0.005 p. p. m. Heavy fall rains 6 months after treatment did not introduce detectable concentrations of herbicide into streams (Norris 1968). A 150-pound man would have to drink 179 gallons of water containing 0.1 p. p. m. 2, 4, 5-T to ingest one one-hundredth of the LD₅₀ (Norris 1967). Therefore, acute toxicity is not a problem, and the short persistence of 2, 4, 5-T in streams makes chronic exposure unlikely.

The forest floor is a major receptor of aerially applied chemicals. Norris (1966) reported 53-percent decomposition of 2, 4, 5-T in 29 days in the highly organic layers of the forest floor. In another study, 87 percent of the 2, 4, 5-T was degraded in 2 months (Norris 1969).

The length of persistence of 2, 4, 5-T in soil varies, but it does not usually carry over from one growing season to the next. Its residual lifetime is influenced by climatic conditions and populations of soil micro-organisms (Alexander and Aleem 1961). Biological detoxication may be complete within a few weeks or may require up to 9 months (Newman et al. 1952; Warren 1954). Where conditions are favorable, it may be detoxified in 1 month (Warren 1954). The 2, 4, 5-trichlorophenol, which is a degradation product of 2, 4, 5-T, is even more readily metabolized than the parent compound (Alexander and Aleem 1961). Obviously, 2, 4, 5-T is not persistent in soil or forest floor.

Recent studies show that 2, 4, 5-T is extensively adsorbed by forest floor material. About 60 percent of the 2, 4, 5-T in solution was adsorbed at equilibrium (30° C.) which was attained in a few hours (Norris 1970). The extensive interaction of 2, 4, 5-T with the forest floor suggests only limited leaching should occur. In an agricultural soil, 2, 4, 5-T remained in the upper 6 inches even after application of 4.5 inches of water over a short period of time (Wiese and Davis 1964). A lack of 2, 4, 5-T residues in streams flowing from treated areas (Norris 1967) suggests that a combination of rapid degradation and resistance to leaching prevents stream contamination.

The concentration of herbicide residues on vegetation depends on rate of application, time following application, amount of precipitation, and type of vegetation being treated. Morton et al. (1967) found 90 to 300 p.p.m. 2,4,5-T on grasses immediately following application of 2 pounds per acre of 2,4,5-T. The range of residues from a 0.5-pound-per-acre application varied from 50 to 110 p.p.m. due to the type and condition of grass at the time of application. Obviously, more spray will be intercepted by a thicker stand of grass.

The persistence of 2,4,5-T residues in vegetation may vary from year to year. The length of time required for one-half of the 2,4,5-T residue to disappear from forage ranged from 1.6 to 2.6 weeks in one study (Morton et al. 1967). Precipitation markedly reduced the residues, indicating it was primarily a surface deposit. However, even in the absence of precipitation, the residues diminished with time due to growth dilution and metabolism of herbicide by the plant^{1/} (Morton et al. 1967).

Klingman et al. (1966) found that the butyl ester of 2,4-D disappeared more rapidly than the 2-ethylhexyl ester of 2,4-D on pasture grasses. Virtually all of the butyl ester of 2,4-D was hydrolyzed to 2,4-D acid in 30 minutes after spraying. Although Klingman's study was with 2,4-D, the similarity of the chemistry of 2,4-D and 2,4,5-T suggests they may behave in a similar manner.

Any 2,4,5-T that is washed from the foliage into the soil will contribute very little to residues in subsequent plant growth. The chlorophenoxyacetic acid herbicides are poorly absorbed and translocated following exposure of roots^{2/ 3/} (Crafts and Yamaguchi 1960).

It is evident from the way 2,4,5-T is used and its behavior in the forest environment that the primary exposure of animals to this chemical will be through consumption of treated vegetation. Let us consider the amounts of 2,4,5-T which might be ingested from the highest residues found (300 p.p.m.) in the study by Morton et al. (1967). A high milk-producing animal might consume up to 10 percent of its

^{1/} Montgomery, M. L. Unpublished data.

^{2/} See footnote 1.

^{3/} Leonard, O. A. Personal communication.

body weight in green forage per day. A 1,000-pound animal consuming 100 pounds of forage containing 300 p.p.m. of 2,4,5-T would ingest 30 milligrams of 2,4,5-T per kilogram of body weight, well below the toxic level.

This is a maximum exposure and would be received only when ingesting forage grasses shortly after treatment. If residue levels drop to less than 10 p.p.m. a few weeks after treatment (Morton et al. 1967), the ingestion level of 2,4,5-T will be no more than 1 mg./kg.^{4/}

The acute and chronic toxicity of 2,4,5-T must be known in order to evaluate the hazard of residues to consumers and applicators. The toxicity of a chemical is absolutely a function of dose. This applies equally to chronic as well as acute exposure. Some of our most useful drugs are toxic when taken in excessive amounts. However, at low dosage levels they do not elicit a toxic response.

The form of the herbicide residue is important from a toxicological standpoint. Rowe and Hymas (1954) reported large differences in the toxicity of various forms of 2,4,5-T to rats, mice, and guinea pigs. The study by Klingman et al. (1966) implies the toxicity of 2,4,5-T esters may be a factor in assessing hazard for short periods, but the toxicity of 2,4,5-T acid is a primary consideration over the long term. The fate and toxicology of the alcohol moiety, a product of ester hydrolysis, may also be important.

The toxicity of 2,4,5-T is intermediate as indicated by its LD₅₀ values of 300 mg./kg. for rats and 100 mg./kg. for dogs (Anonymous 1967). It is not an extremely toxic compound like Parathion (LD₅₀, about 10 mg./kg.) but is of a higher order of toxicity than many other herbicides. A sheep fed a daily dose of 100 mg./kg. of an amine salt of 2,4,5-T for 481 days was unaffected. In a similar experiment, 369 daily doses of 100 mg./kg. of 2,4,5-T ester were required to kill sheep (Palmer and Radeleff 1964). It is nearly inconceivable that an animal would ever be exposed to such extreme levels. Chicks were unaffected by 100 p.p.m. of 2,4,5-T in their rations (Anderson et al. 1962).

^{4/} This common notation means weight of toxicant per kilogram of body weight of organism exposed.

Long-term chronic toxicity is important only when a chemical is retained by the organism for extended periods. If a compound is readily eliminated, the acute and short-term chronic toxicities will adequately describe its toxicity.

Feeding studies with various animals have shown that 2,4,5-T is rapidly excreted. Erne (1966) reported the major route of elimination of 2,4,5-T from pigs, calves, and rats dosed with 100 mg./kg. was in the urine. Repeated doses did not result in retention or accumulation of herbicide. A cow which received 5 p.p.m. 2,4,5-T in its feed eliminated essentially all of the chemical within 2 days following exposure, and no 2,4,5-T was found in the milk (St. John et al. 1964). Mice injected with 100 mg./kg. 2,4,5-T eliminated approximately 70 percent within 24 hours (Zielinski and Fishbein 1967).

Low residues of 2,4,5-T were found in blacktail deer up to 43 days after spraying (Newton and Norris 1968). The highest residues were found in the feces, urine, and stomach contents; negligible residues were found in body parts used for human consumption.

Evaluation of animal exposure to 2,4,5-T leads to the following conclusions:

1. Dairy and beef animals allowed to forage on treated grasses will ingest highest concentrations of 2,4,5-T shortly after application.
2. Because of degradation, growth dilution, and other factors, residues of 2,4,5-T will be markedly reduced a few weeks after application.
3. The herbicide is rapidly excreted; there is no accumulation in animal tissues.
4. There is no detectable residue in milk; therefore, man will not be exposed to 2,4,5-T through consumption of milk or meat from animals foraging on treated grasses.
5. Long-term chronic exposure of wildlife should not occur since 2,4,5-T does not persist for long periods in the forest, and repeated applications are rare.

It is evident that the hazard of 2,4,5-T in the forest environment is low when the chemical is properly used. The reasons for this are: (a) the behavior of 2,4,5-T in the forest environment makes it unlikely that organisms will be exposed to acutely toxic doses of chemicals, (b) the rapid excretion of ingested 2,4,5-T lessens the likelihood of undesirable effects from other than excessive exposure, and (c) the comparatively short persistence of 2,4,5-T in the environment precludes the possibility of prolonged exposure to significant residues. When used in the forest according to tested procedures, 2,4,5-T offers minimal hazard to man and his environment because the large and prolonged doses required to cause significant biological effects are not likely to occur.

LITERATURE CITED

Anonymous.

1967. 2,4,5-trichlorophenoxyacetic acid. *In* Herbicide handbook of the Weed Society of America, Hull, H. M. et al. (eds.) pp. 273-275. Geneva, New York: Humphrey Press.

-
1969. Thalidomide effect from defoliants? *Sci. Res.* 4(23): 11-12.

Alexander, M., and Aleem, M. I.

1961. Effect of chemical structure on microbial decomposition of aromatic herbicides. *J. Agr. Food Chem.* 9: 45.

Anderson, A., Kivimae, A., and Wadne, C.

1962. The toxicity of some herbicides to chicks. *Kgl. Lantbrukskogsol och. Statens Lantbruksforsok., Statens Husdjursforsok.* No. 155, 18 pp. (Also in *Chem. Abstr.* 59: 5547h. 1963.)

Crafts, A. S.

1967. Vegetation management and the welfare of society. *In* Herbicides and Vegetation Management Symp., pp. 1-7. Oregon State University, Corvallis.

_____ and Yamaguchi, S.

1960. Absorption of herbicides by roots. *Amer. J. Bot.* 47: 248-255.

Erne, K.

1966. Distribution and elimination of chlorinated phenoxyacetic acid in animals. *Acta. Vet. Scand.* 7: 240.

Klingman, Dayton L., Gordon, Chester H., Yip, George, and Burchfield, H. P.

1966. Residues in the forage and in the milk from cows grazing on forage treated with esters of 2,4-D. *Weeds* 14: 164-167.

Morton, Howard L., Robison, E. D., and Meyer, Robert E.

1967. Persistence of 2,4-D, 2,4,5-T and dicamba in range forage grasses. *Weeds* 15: 268-271, illus.

Nelson, Bryce.

1969. Herbicides: Order on 2,4,5-T issued at unusually high level. *Science* 166: 977-979.

Newman, A. S., Thomas, J. R., and Walker, R. L.

1952. Disappearance of 2,4-D acid and 2,4,5-T acid from soil. *Soil Sci. Soc. Amer. Proc.* 16: 21, 24.

Newton, Michael, and Norris, Logan A.

1968. Herbicide residues in blacktail deer from forests treated with 2,4,5-T and atrazine. *Western Soc. Weed Sci. Proc.*, pp. 32-34.

Norris, Logan A.

1966. Degradation of 2,4-D and 2,4,5-T in forest litter. *J. Forest.* 64: 475-476, illus.

-
1967. Chemical brush control and herbicide residues in the forest environment. *In* *Herbicides and Vegetation Management Symp.*, pp. 103-123. Oregon State University, Corvallis.

-
1968. Stream contamination by herbicides after fall rains on forest lands. *Western Soc. Weed Sci. Res. Progr. Rep.*, pp. 33-34.

Norris, Logan A.

1969. Degradation of several herbicides in red alder forest floor material. Western Soc. Weed Sci. Res. Progr. Rep., pp. 21-22.

-
1970. Adsorption and desorption of four herbicides on forest floor material. Northwest Sci. [In press.]

Palmer, J. S., and Radeleff, R. D.

1964. The toxicologic effects of certain fungicides and herbicides on sheep and cattle. Ann. N. Y. Acad. Sci. 111: 729-736.

Rowe, V. K., and Hymas, T. A.

1954. Summary of toxicological information on 2,4-D and 2,4,5-T type herbicides and an evaluation of the hazards to livestock associated with their use. Amer. J. Veterinary Res. 15: 622-629.

St. John, L. E., Wagner, D. G., and Lisk, D. J.

1964. Fate of atrazine, kuron, silvex, and 2,4,5-T in the dairy cow. J. Dairy Sci. 47: 1267-1270.

Tarrant, R. F., and Norris, L. A.

1967. Residues of herbicides and diesel oil carriers in forest waters: a review. In Herbicides and Vegetation Management Symp., pp. 94-102. Oregon State University, Corvallis.

Warren, G. F.

1954. Rate of leaching and breakdown of several herbicides in different soils. North Central Weed Control Conf. Proc. 11: 5.

Wiese, A. F., and Davis, R. G.

1964. Herbicides movement in soil with various amounts of water. Weeds 12: 101-103, illus.

Zielinski, Walter L., and Fishbein, Lawrence.

1967. Gas chromatographic measurement of disappearance rates of 2,4-D and 2,4,5-T acids and 2,4-D esters in mice. J. Agr. Food Chem. 15: 841-844, illus.

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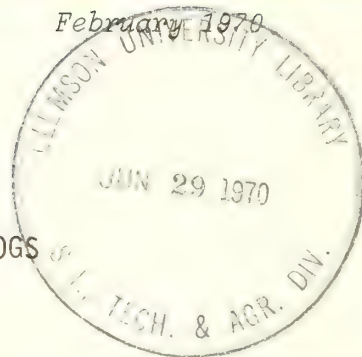
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ESTIMATING VOLUME OF DOUGLAS-FIR BUTT LOGS

by

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ABSTRACT

Describes development of equation to get close estimates of cubic-foot volume of flaring butt logs (S.E. = 3 percent) based on measurement of length and top and butt inside bark diameters.

Several methods of estimating cubic-foot volume of butt logs are commonly used. Most are based on three measurements or on two measurements and an estimate. The needed information includes length, top diameter inside bark (d.i.b.), and a butt diameter inside bark. This last item is usually estimated, by either guessing the taper, eyeballing what the diameter would be with the butt flare removed, or estimating the diameter a given distance above the butt cut. These estimates are often inaccurate and volume estimates might be improved if a measurement of butt diameter were used. Use of a butt measurement requires an allowance for butt flare when calculating volume.

Since butt logs are often fluted as well as flared, the only truly accurate measurement of volume is by displacement of water. This is generally impracticable so some substitute is needed. Measurement of diameter outside bark (d.o.b.) and bark thickness at short intervals gives close estimates of volume but is too expensive for most purposes. Also, it requires allowance for fluting. This allowance can be made on the butt cut by visualizing an irregular closed curve that excludes as much wood in projections as it includes air and bark in fissures. Once this allowance is made, the diameter is estimated as the average of the measured long axis of the closed curve and the one at right angles to it. A model was sought that would give good volume estimates based only on length, top d.i.b., and this adjusted butt d.i.b.

The classical Neiloid^{1/} is often suggested as a figure that exhibits butt flare. If this were true, butt logs would resemble frustums of Neiloids. It was found that the middle diameter of a Neiloid with top diameter 60 percent of base diameter is 79.15 percent of the base--imperceptibly smaller than the 80 percent middle diameter of the frustum of a cone with the same end diameters. Since butt log shapes are more like bells of trumpets than ice cream cones, neither the Neiloid nor cone alone will serve as a model.

Several models that describe a flaring curve were tested but found unsuitable for empirical least square regression fitting. The model finally used came from the notion of joining a cylinder to the frustum of a cone. The cylinder approximates the upper part of the log and the cone the basal flare. The equation for the volume of such a figure is $V = b D_u^2 L_u + b (D_u^2 + D_u D_b + D_b^2) L_b / 3$

where V = volume

D_u = upper diameter

D_b = basal diameter

L_u = upper length

L_b = basal length

$b = 5.454 \times 10^{-3}$ (with length in feet and
diameter in inches)

^{1/} A Neiloid is a solid of revolution generated by revolving Neil's parabola written in the form: $d = ah^{3/2}$ around its h -axis. The locus of this equation on a plane is the profile of the figure. If h is height and d is diameter, h is measured from the top of the tree downward.

Since the relative lengths of the upper and basal ends of such a figure that would best simulate a butt log were unknown, this equation was fit in the form $V = b_1 D_u^2 L + b_2 D_u D_b L + b_3 D_b^2 L$ (where L is total log length). Usually, when this was fit^{2/} to logs of a single length, the third term did not significantly reduce residual variation. The two terms most often significant were $D_u^2 L$ and $D_u D_b L$. When these were fit to data for logs grouped by lengths, the b_i coefficients varied linearly with length. This suggested adding the cross products of the independent variables with length to the model fitted to logs of all lengths. Stepwise regressions led finally to the model:

$$V = b_1 L D_u^2 + b_2 L D_u D_b - b_3 L^2 D_u D_b$$

This equation corresponds to a composite solid comprised of a cylinder with the diameter of the small end and a concave solid of revolution resembling a truncated conoid (fig. 1). Obviously, this will be smaller than a butt log at the juncture of the cylinder and the conoid. This appears to compensate for the butt of the log being more concave than the conoid. Fitting this regression model by least squares determines coefficients that best make these compensations.

In these regression fits, the sum $(b_1 + b_2 - b_3 L)$ was close to 5.454×10^{-3} . The third term in the equation adjusts for the lower percent of log volume in butt flare in longer logs.

This model and several others were tested on stem profiles of 112 Douglas-fir butt logs. Forty-eight of these profiles were based on tree measurement data on file at the Pacific Northwest Forest and Range Experiment Station. The data included stump d.i.b., d.b.h.i.b., and upper stem d.i.b. measurements at 10-foot intervals. The other 64 profiles were based on measurements of the bottom five veneer bolts of trees in mill recovery studies by the Timber Quality and Wood Utilization Project of the Pacific Northwest Forest and Range Experiment Station. The range of d.b.h. was 15 to 75 inches.

^{2/} In regression analyses of such data, V is transformed to a dimensionless ratio by dividing by $D_u^2 L$, $D_u D_b L$, or $D_b^2 L$ to avoid high correlations among variables with the same order of dimensions. Such high correlations sometimes lead to acceptance of oversimplified functions. In these transformations, all variables for each sample unit are divided by the same factor. These transformations have the added effect of reducing or eliminating correlation of error variance with independent variables.

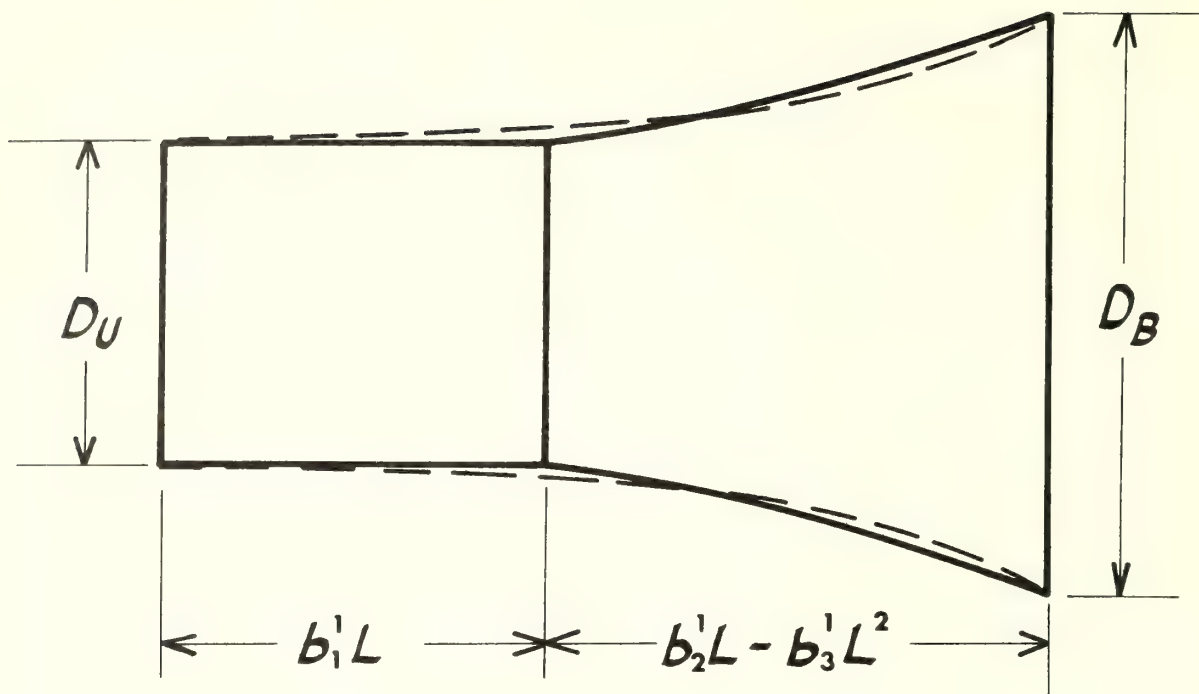


Figure 1.--Profile described by butt log equation (dashed line indicates one possible butt log profile).

Diameters on these profiles were measured at 2-foot intervals, and volumes were calculated as described by Johnson^{3/} using the Smalian formula.^{4/} Volumes were calculated for the butt 8-, 16-, 24-, and 32-foot logs of each tree.

^{3/} Johnson, Floyd A. A technique for calculating cubic volumes in butt logs of trees. J. Forest. 55: 666, illus. 1957.

^{4/} Grosenbaugh, L. R. Tree form: definition, interpolation, extrapolation. Forest. Chron. 42: 444-457, illus. 1966.

This article states that concavity or convexity becomes relatively unimportant in sections short enough that the smaller diameter is at least 80 percent of the larger diameter. With this diameter ratio, the volume of a Neiloid frustum is 98.9 percent of the volume of a paraboloid frustum; with an end ratio of 90 percent, the volume ratio is 99.7 percent. Of course, butt logs are much more concave than Neiloids, but few 2-foot sections have end ratios under 90 percent, so the timesaving use of Smalian's equation appears justified.

The Timber Quality and Wood Utilization Project data were from widely separated locations--Medford and Mapleton, Oreg., and Darrington, Wash. Analysis of covariance indicated no significant differences among regressions fitted to data from these three areas. These regressions were then compared with the regression for the older data. It was found that regression surface shapes varied more than could be attributed to chance.

Volume estimates from various regressions were compared. Estimates based on the regression for old data were higher for logs with extreme taper and lower for logs with little taper than estimates based on the pooled regression for recent data. With average taper (81 percent end ratio), estimates were the same. The pooled regression based on all data gave estimates within 1.5 percent of the other equations for all logs and within 1 percent for 98 percent of the logs. It has a standard error of 3 percent. This pooled equation appears to be sufficiently accurate for both groups of data and, therefore, is likely to do a good job of estimating volumes for other Douglas-fir butt logs. The equation is:

$$V = 2.233 \times 10^{-3} \times D_u^2 L + 3.687 \times 10^{-3} \times D_u D_b L - 5.654 \times 10^{-6} \times D_u D_b L^2$$

To get accurate cubic-foot volume estimates with this equation, diameters should be recorded to the nearest one-tenth inch and actual lengths (no trim allowance) to the nearest one-tenth foot if possible. With large, rough logs, the smallest feasible units of measurement should be used.

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ALBINO SEEDLINGS OF WHITE SPRUCE

by

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ABSTRACT

In two tests, seed collected from a stand of mature white spruce trees (*Picea glauca* (Moench) Voss) produced 1.5 and 1.9 percent albino seedlings. None of the albinos lived more than a few weeks, and all had normal chromosome counts of $2n=24$. Chlorophyll deficiency is evidently a recessive character, but these observations did not resolve current questions of whether the character is controlled by one or more genes or is linked with an embryonic lethal. The albino seedlings may have resulted from self-fertilization of one or more parent trees.

Albinism, as well as lesser degrees of chlorophyll deficiency, was reported among gymnosperms in seedlings of eastern white pine (*Pinus strobus* L.) (Johnson 1945), Austrian pine (*Pinus nigra* Arnold) (Johnson 1948), Scotch pine (*Pinus sylvestris* L.) (Eiche 1955), red pine (*Pinus resinosa* Ait.) (Fowler 1962), western white pine (*Pinus monticola* Dougl.) (Barnes *et al.* 1962), slash pine (*Pinus elliottii*

Engelm.) (Squillace and Kraus 1963), jack pine (*Pinus banksiana* Lamb.) (Fowler 1965a), Norway spruce (*Picea abies* (L.) Karst.) (Langner 1953), Serbian spruce (*Picea omorika* (Pancic) Purkyne) (Langner 1959), and blue spruce (*Picea pungens* Engelm.) (Cram 1960). Nienstaedt^{1/} and Fowler^{2/} both observed chlorophyll deficiency after selfing white spruce, but neither has yet published his data. This Note reports albinism among seedlings from a wild source of open-pollinated white spruce seed in Alaska.

METHOD AND RESULTS

Cones were collected in August 1968, just prior to seed dispersal from several 180-year-old white spruce trees (*Picea glauca* (Moench) Voss), located approximately 25 kilometers southwest of College, Alaska, at the Bonanza Creek Experimental Forest (64°51'N, 147°44'W). Seeds were extracted and planted the same season.

In two tests, respectively, six albinos were recovered from 400 seeds (1.5 percent) and 17 from among 900 seeds (1.9 percent). The albino seedlings had white cotyledons and pink hypocotyls, but none of the other morphological characters deviated significantly from the variation found in normal seedlings (fig. 1). Most albino seedlings remained alive for 2 or 3 weeks.



Figure 1.—Albino seedling from Alaskan white spruce seed collected from open-pollinated trees.

^{1/} Dr. Hans Nienstaedt, Institute of Forest Genetics, Rhineland, Wis., personal correspondence.

^{2/} Dr. D. P. Fowler, Dep. of Fisheries and Forestry, Fredricton, N. B., Canada, personal correspondence.

Eleven albino and four normal seedlings were examined cytologically with a propiono-orcein squash technique, and cells from root and needle meristems from all plants had the normal chromosome number of $2n=24$ (fig. 2).

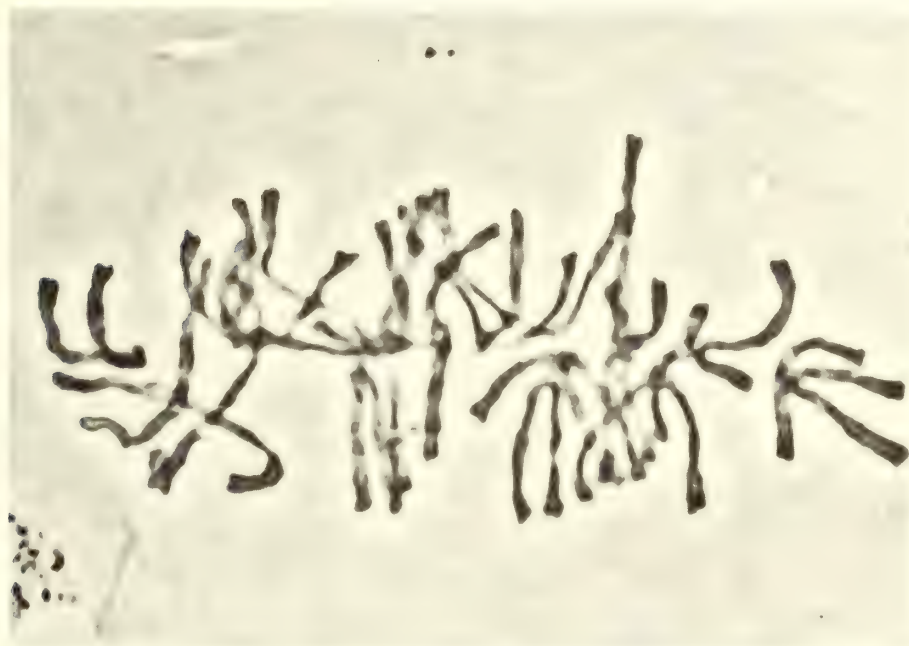


Figure 2.—Somatic metaphase stage in one cell from an albino white spruce seedling, with $2n=24$ chromosomes.

DISCUSSION

The frequency of self-fertility appears to be generally higher among the spruces than the pines. Selfing results in an inbreeding depression for both species. The exception is for red pine (Fowler 1965b), which may be largely homozygous for most alleles. Fowler (1964) reported mutant seedlings in red pine having light yellow-green cotyledons and suggested that they were homozygous for a single recessive gene. He explained the divergence from an expected 1:3 monohybrid ratio as a selection against zygotes, pro-embryos or embryos homozygous for that mutation. Sorensen (1967) suggested that the recessive allele for albinism may be linked with an embryonic lethal. Mergen et al. (1965) reviewed the literature on inbreeding depression from selfing and concluded that it was caused by an accumulation of homozygous alleles in the progeny of heterozygous parents. They went on to give cytological evidence of embryo failure after fertilization but also explained that the degree of embryo failure varied between parent trees. They found no barrier to either self-pollination or self-fertilization in white

spruce. They did not report albino seedlings, perhaps because only large seeds were planted.

The albino white spruce seedlings reported in this Note were all devoid of chlorophyll, but their origin is uncertain, whether from one or several parent trees. Total albinism suggests control by one recessive gene. However, the different degrees of chlorophyll deficiency reported among gymnosperms seem to favor an explanation based on a multiple-gene effect. Whatever the genetic control, results of past work by others on selfing indicate that the albino white spruce seedlings may have resulted from self-fertilization and that a low frequency of albinism is common among most wild spruces.

LITERATURE CITED

- Barnes, B. V., Bingham, R. T., and Squillace, A. E.
1962. Selective fertilization in *Pinus monticola* Dougl. II. Results of additional tests. *Silvae Genet.* 11(4): 103-111.
- Cram, W. H.
1960. Shelterbelt tree breeding. Seventh Meeting Comm. Forest Tree Breeding Can. Proc. Part II, pp. D 1-5.
- Eiche, V.
1955. Spontaneous chlorophyll mutations in Scots pine (*Pinus sylvestris* L.). Medd. Statens Skogsforsknings Inst. 45(13): 1-69. (Forest Abstr. 17: 1242 (1956).)
- Fowler, D. P.
1962. Initial studies indicate *Pinus resinosa* little affected by selfing. Ninth Northeastern Forest Tree Impr. Conf. Proc. 1961: 3-8.
-
1964. Pre-germination selection against a deleterious mutant in red pine. *Forest Sci.* 10: 335-336.
-
- 1965a. Natural self-fertilization in three jack pines and its implications in seed orchard management. *Forest Sci.* 11: 55-58.
-
- 1965b. Effects of inbreeding in red pine, *Pinus resinosa* Ait. II. Pollination studies. *Silvae Genet.* 14: 12-23.
- Johnson, A. G.
1948. Albinism in Austrian pine. *J. Hered.* 39: 9-10.

Johnson, L. P. V.

1945. Reduced vigor, chlorophyll deficiency, and other effects of self-fertilization in *Pinus*. Can. J. Res. 23C: 145-149.

Langner, W.

1953. Eine Mendelspaltung bei *Aurea* - Formen von *Picea abies* (L.) Karst. als Mittel zur klärung der Befruchtungsverhältnisse im Walde. Z Forstgenet 2(3): 49-51.

-
1959. Selbstfertilität und Inzucht bei *Picea omorika* (Pancic) Purkyne. Silvae Genet. 8: 84-93.

Mergen, F., Burley, J., and Furnival, G. M.

1965. Embryo and seedling development in *Picea glauca* (Moench) Voss after self-, cross-, and wind-pollination. Silvae Genet. 14: 188-194.

Sorensen, F.

1967. Linkage between marker genes and embryonic lethal factors may cause disturbed segregation ratios. Silvae Genet. 16: 132-134.

Squillace, A. E., and Kraus, J. F.

1963. The degree of natural selfing in slash pine as estimated from albino frequencies. Silvae Genet. 12: 46-50.

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PNW-119

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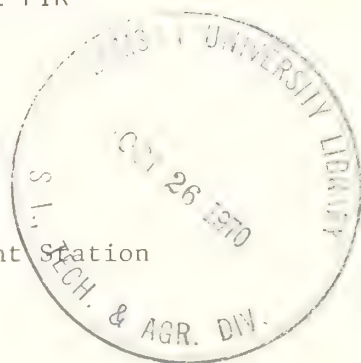
PRELIMINARY SITE INDEX CURVES FOR NOBLE FIR
FROM STEM ANALYSIS DATA

by

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and

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Abstract

Preliminary polymorphic site index curves were developed using stem analysis data from 54 plot locations in Oregon and Washington. Site index reference age is 100 years at breast height, and total height is measured from average ground level. A family of 11 curves was obtained from four polymorphic curves by interpolation and proportional methods. The curves were extended from 250 to 350 years of age to provide site index values for these older age classes.

The curves were based on tallest dominants only; therefore, the tallest dominant should be used when estimating the site index of a particular area. Curves based on additional stem analyses of noble fir will be produced in the future.

INTRODUCTION

Cooperative stem analysis studies were undertaken by the U.S. Forest Service and Oregon State University in June 1965 to obtain information for managing the upper-slope forest complex. The studies were especially aimed at collection of growth data for old-growth noble fir. However, similar data were also collected for species associated with noble fir and will be used in comparative growth studies.

The usual upper-slope forest stand is an uneven-aged mixed coniferous type. To obtain an estimate of site in this forest type, noble fir (*Abies procera* Rehd.) was selected for study because it is an intolerant species and is usually free from suppression effects. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is perhaps as intolerant of shade as noble fir, but it does not occur as frequently in the upper-slope, mixed-conifer type.

Noble fir trees were felled at 54 locations from McKenzie Pass in the Central Oregon Cascades to Mount Rainier in the Washington Cascades. Location lists of timber stands containing noble fir were compiled from information provided by National Forest personnel, loggers, and research workers. Study areas were selected from the lists to provide a complete range from best to poorest growing conditions as evidenced by height in relation to age, soil, slope and exposure factors, and composition and frequency of understory vegetation. We relied strongly on preliminary site quality and plant association relationships explained by Franklin (1966) for recognition of site differential.

A single, tallest dominant noble fir was felled and sectioned at each plot location.^{1/} Previous exploratory work (Herman 1967) showed that, with minor exceptions, the tallest dominant tree had been the tallest throughout the life of the stand.

ANAMORPHIC VERSUS POLYMORPHIC SITE INDEX CURVES

Various methods of classifying sites have been used, such as indicator plants, volume, and soil condition, but the most common measure of site quality is site index, the height of a specified stand component at a given age (Spurr 1952). In the past, many site index curves have been anamorphic, that is, proportional curves based on one master curve. A weakness of anamorphic curves is that they have the same shape for high and low sites (Smith, Ker, and Heger 1960). Bull (1931) found in red pine that the period of maximum height growth varied with site class. Low sites exhibited their period of maximum height growth at an older age than the high sites did.

Polymorphic curves are curves that are not proportional to each other (Bull 1931). Since polymorphic site curves do not have the same shape or trend for each site classification (Spurr 1964), stem analysis data must be used in the construction of such curves.

^{1/} Each plot was approximately one-fourth acre.

ANALYSIS METHOD

For each tree sectioned, the height of each section above breast height was plotted over total number of years the tree required to attain that section height. The points were connected with a smoothed curve. Heights were then read from the curves at 10-year intervals of total breast-height age. These heights and ages were the data used in the subsequent analysis. Heights for ages over 250 years were eliminated from further analysis because the older age classes were inadequately represented. In addition, site curves can be distorted if the older trees differ in average site index from the younger trees (Curtis 1964).

A frequency distribution of sample tree heights at 100 years of age was made to determine their range. Heights ranged from 50 to 150 feet, with most of the trees in the 80- to 120-foot class. Data were sorted into four height/age groups on the basis of site indices, and a separate curve was fitted to each group.

STEPWISE REGRESSION

Two general equations were used to analyze the four groups of data. These models are:

$$1. \log_{10} (\text{Height}) = a + b (\text{Age}^K)$$

where

K are selected values from -2.00 to -0.10

$$2. \text{Age}^2/\text{Height} = a + b (\text{Age}) + c(\text{Age}^2) \text{ (Prodan 1968)}$$

By means of a stepwise regression computer program, two curves based on the above two models were fitted to each data group. Graphical comparisons indicated that Model 2 provided the better fit. The equations for the four major site groupings are as follows:

Group A

$$(\text{Age})^2/\text{HT} = 13.64781 + 0.19937 (\text{Age}) + 0.00416 (\text{Age})^2$$

Group B

$$(\text{Age})^2/\text{HT} = 10.11508 + 0.40115 (\text{Age}) + 0.00426 (\text{Age})^2$$

Group C

$$(\text{Age})^2/\text{HT} = 19.10187 + 0.50996 (\text{Age}) + 0.00490 (\text{Age})^2$$

Group D

$$(\text{Age})^2/\text{HT} = 12.68825 + 1.05408 (\text{Age}) + 0.00501 (\text{Age})^2$$

The four equations were solved for heights at 10-year intervals of age (the four curves are shown in fig. 1). Note that the axes are graduated for *height above breast height and age at breast height*. Breast height was selected as a base not only because it is more convenient to use, but also because it provides a set of curves little influenced by early stand history (Husch 1956).

Table 1 gives root residual mean square and multiple correlation coefficients for each of the site group equations.

A graphical test for polymorphism indicated the site index curves were polymorphic. Previous investigation of scatter diagrams for the individual site groups indicated that polymorphism might exist. The graphical test on the four major curves confirmed this fact.

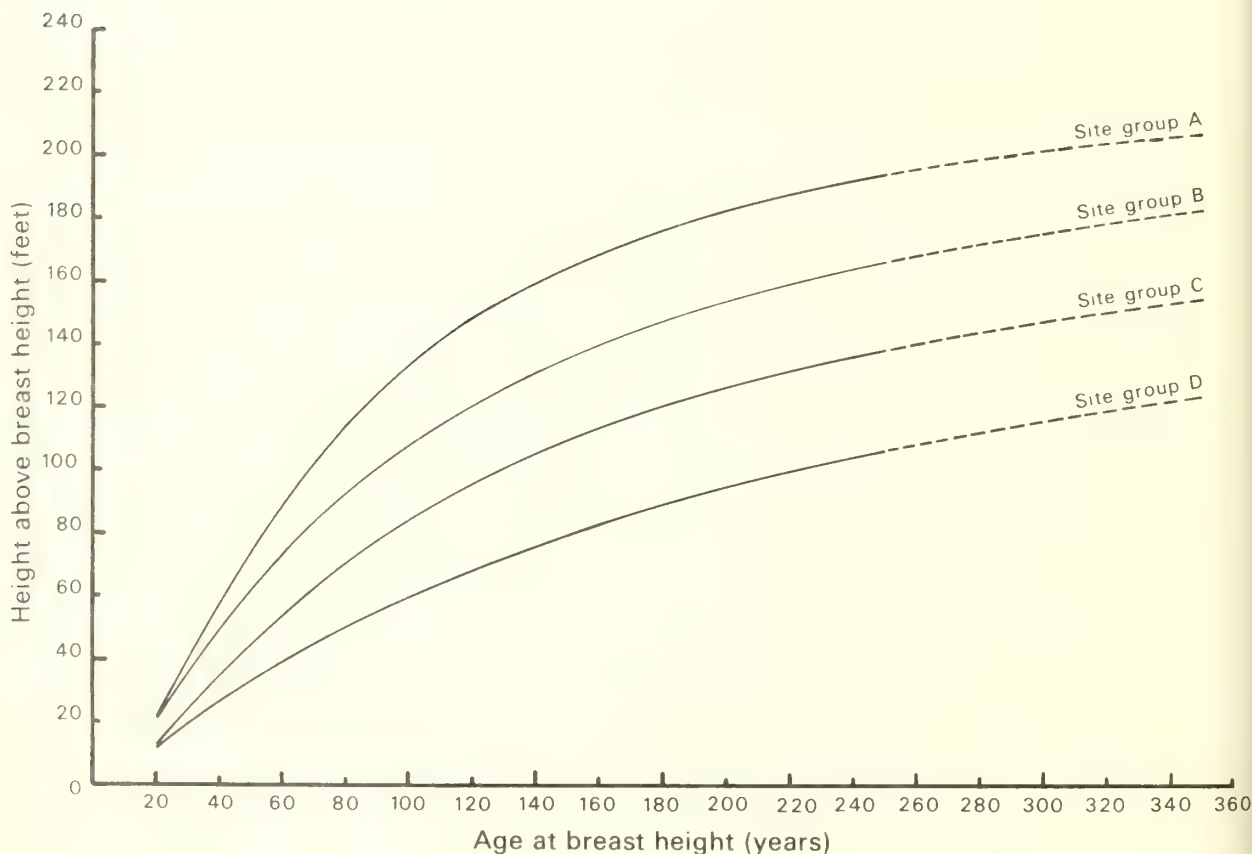


Figure 1.--Curves fitted to group data.

Table 1.--Root residual mean square and multiple correlation coefficient for each site group equation^{1/}

Site group	Root residual mean square ^{2/}	Multiple correlation coefficient
A	13.27	0.989
B	11.46	.994
C	20.53	.986
D	40.86	.972

^{1/} Values refer to (Age)²/Height.

^{2/} Standard deviation from regression line.

FAMILY OF SITE INDEX CURVES

A family of 10-foot index curves at the standard age of 100 was constructed from the four polymorphic curves. An adjustment of 4.5 feet was made to the family of curves to obtain total height since the four major curves were based on height above breast height. Two proportional curves, a 45.5-foot and a 55.5-foot, were obtained from the Site D master curve. Likewise, the 135.5-foot and 145.5-foot curves were proportional curves obtained from the Site A master curve. The 4.5-foot adjustment was added to each of these curves to obtain total height. Thus, the curves became 50, 60, 140, and 150 feet, respectively, at the standard age of 100 years.

The construction of the other curves, 70, 80, 90, 100, 110, 120, and 130, was not as simple. Since each curve in question lies between two major curves, a problem arose as to which major curve should influence the minor curve. A reasonable approach to the problem is to have both major curves influence the 10-foot interval curves that lie between them. The method used is as follows:

1. Calculate the height interval between the two major curves of interest at 10-year intervals.
2. At the index age, calculate the height interval between the curve that is to be constructed and the lower major site curve. In this case, the curves to be constructed are 65.5, 75.5, 85.5, 95.5, 105.5, 115.5, and 125.5.

3. Divide the height interval obtained in step 2 by the height interval between the two major curves at the index age.
4. Multiply each interval obtained in step 1 by the value obtained in step 3. This gives a value for each 10 years of age.
5. Add each 10-year age value obtained in step 4 to the height of the lower major site curve at corresponding age.
6. Add the 4.5-foot adjustment to provide curves of total height.

Table 2 presents in detail average total height of tallest dominant trees by age and site index. The 10-foot noble fir site index curves are shown in (fig. 2).

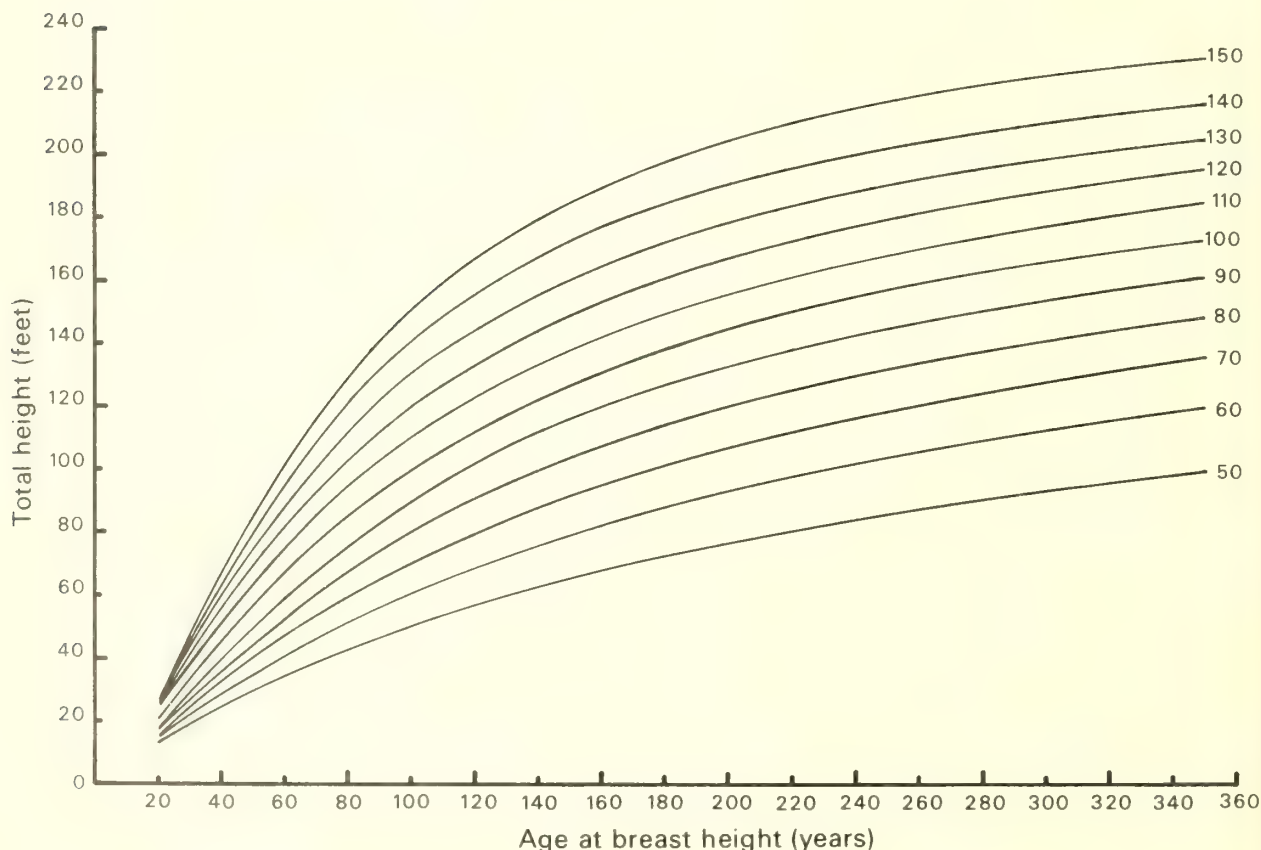


Figure 2.--Family of site index curves for noble fir.

Table 2.--Average total height of tallest dominant trees by breast-height
age and site index^{1/}

Age in years	Site Class IV Site Index--		Site Class III Site Index--			Site Class II Site Index--			Site Class I Site Index--		
	50	60	70	80	90	100	110	120	130	140	150
----- Feet -----											
20	13	15	16	17	18	21	24	25	25	26	27
30	19	22	24	26	28	33	38	40	42	44	47
40	24	28	32	35	39	45	52	56	59	62	66
50	29	34	40	44	50	57	64	70	74	79	85
60	34	40	47	53	59	67	75	82	88	95	102
70	38	46	53	60	68	77	86	93	101	109	116
80	42	51	59	68	76	85	95	103	112	120	129
90	46	56	65	74	83	93	103	112	122	131	140
100	50	60	70	80	90	100	110	120	130	140	150
110	53	64	75	85	96	106	117	127	137	148	159
120	57	68	79	91	102	112	123	133	144	155	166
130	60	72	84	95	107	117	128	139	150	161	173
140	63	75	88	99	111	122	133	144	155	167	179
150	65	79	91	103	116	126	137	149	160	172	184
160	68	82	95	107	119	131	142	153	164	176	189
170	70	85	98	111	123	134	145	157	168	180	193
180	72	87	101	114	126	138	149	160	172	184	197
190	75	90	104	117	130	141	152	164	175	187	200
200	77	93	107	120	132	144	155	167	178	190	203
210	79	95	109	122	135	147	158	169	181	192	206
220	81	97	112	125	138	149	161	172	183	195	209
230	82	99	114	127	140	152	163	174	185	197	211
240	84	102	116	129	142	154	166	177	188	199	214
250	86	104	118	131	144	156	168	179	190	201	216

260	87	105	120	133	146	158	170	181	191	203	218
270	89	107	122	135	148	160	172	183	193	205	220
280	90	109	124	137	150	162	174	184	195	206	221
290	92	111	126	139	152	163	175	186	196	208	223
300	93	112	128	140	153	165	177	188	198	209	224
310	94	114	129	142	155	167	179	189	199	211	226
320	95	115	131	143	156	168	180	190	200	212	227
330	96	117	132	145	157	169	181	192	202	213	228
340	98	118	134	146	159	171	183	193	203	214	229
350	99	119	135	148	160	172	184	194	204	215	230

^{1/} Values below the dashed line were obtained by extrapolation of curves.

The 10-foot curves were checked by comparing them graphically with dissected trees not used in the analysis. The checking consisted of estimating the site index of a dissected tree at two ages in its development. The first age was 80 years, and the second age was 220 years or greater. The two estimates of site were always quite close to one another, which indicated the 10-foot site curves were reasonably shaped.

SUMMARY

The polymorphic site index curves should provide reliable estimates of site index for noble fir found between McKenzie Pass in Oregon and the White River drainage north of Mount Rainier in Washington.

In using the site curves or site index table, use total height of the tallest dominant or dominants since the curves are based on the tallest dominant noble fir within one-fourth acre. According to Dahms (1966), tallest trees in the stand give the best estimate of site. In estimating site index, *breast height age and total tree height above average ground level* should be used.

LITERATURE CITED

Bull, Henry.

1931. The use of polymorphic curves in determining site quality in young red pine plantations. J. Agr. Res. 43: 1-28, illus.

Curtis, Robert O.

1964. A stem analysis approach to site-index curves. Forest Sci. 10: 241-256, illus.

Dahms, Walter G.

1966. Effect of kind and number of measured tree heights on lodge-pole pine site-quality estimates. Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PNW-36, 8 pp.

Franklin, Jerry Forest.

1966. Vegetation and soils in the subalpine forests of the southern Washington Cascade Range. Diss. Abstr. 27(6): 1746B-1747B.

Herman, Francis R.

1967. Growth comparisons of upper-slope conifers in the Cascade Range. (Abstr.) Northwest Sci. 41: 51-52.

Husch, B.

1956. Use of age at d.b.h. as a variable in the site index concept. J. Forest. 54: 340.

Prodan, Michall.

1968. Forest biometrics. 447 pp. Oxford [etc.] Pergamon Press.
(English trans. by Sabine H. Gardiner)

Smith, J. Harry G., Ker, J. W., and Heger, L.

1960. Natural and conventional height-age curves for Douglas-fir and some limits to their refinement. Univ. British Columbia Res. Pap. 30, 6 pp.

Spurr, Stephen Hopkins.

1952. Forest inventory. 476 pp. New York, Ronald Press.

1964. Forest ecology. 352 pp., illus. New York, Ronald Press.

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PNW-120

May 1970

Controlled Field Test of Stabilized Pyrethrins Against the Western Hemlock Looper

by

Richard R. Mason, *Insect Ecologist*



Use Pesticides Safely
FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE



The Kenya Pyrethrum Company of Newark, N. J., furnished the stabilized pyrethrins and financed most of the experiment. Field aspects of the test were made possible by the cooperation of R. G. Mitchell, C. Sartwell, T. C. Tigner, H. G. Paul, and V. M. Carolin of the Pacific Northwest Forest and Range Experiment Station. Appreciation is also extended to L. F. Pettinger, J. Mounts, and others of Region 6, U.S. Forest Service, for their cooperation on many phases of the test and to R. DeWitz of the Mount Baker National Forest for photography.

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife -- if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

ABSTRACT

A new stabilized formulation of pyrethrins was field tested against larvae of the western hemlock looper by spraying from a helicopter. A selected number of larvae were placed in foliage on platforms where they were fully exposed to the spray and on small trees where they were partially screened from direct spray contact. Ninety-nine percent and 94 percent of the larvae on the platforms and on the trees, respectively, were paralyzed or killed by the insecticide. Most of the larvae fully exposed on the platforms were knocked down within a few minutes after spraying, whereas knockdown of larvae in the trees occurred over a considerably longer period of time. Recovery rate of paralyzed larvae was higher for those that were slow to be knocked down than for larvae knocked down quickly.

INTRODUCTION

Pyrethrins are natural insecticidal compounds usually extracted from flowers of the pyrethrum plant, *Chrysanthemum cinerariaefolium* Vis. They are highly toxic to many lepidopterous defoliators including the western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst). Moreover, they have a low level of toxicity to mammals and are generally regarded as among the safest of insecticides. However, because of their rapid deterioration in sunlight, previous formulations of pyrethrins have been of little value in controlling forest defoliators.

Recently, a stabilized formulation of the pyrethrins has shown promise of maintaining toxicity in direct sunlight for a much longer period of time. Accordingly, a field test was conducted to determine whether this new formulation of pyrethrins was durable when applied by helicopter in a natural forest situation and whether it had promise as a control for the western hemlock looper.

EXPERIMENTAL METHODS

The insecticide used was a new stabilized formulation of pyrethrins developed at the Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.^{1/}

The test formulation, furnished by the Kenya Pyrethrum Company of Newark, N. J., was applied by helicopter at the rate of 0.1 pound active ingredient in one-half gallon mineral oil per acre. Based on pressure in the spray

^{1/} A patent for the stabilized pyrethrins is pending. The authors of the patent are Raymond P. Miskus and Theresa L. Andrews.

system and size of nozzles, the delivered droplet size was estimated to be 120 μ mass median diameter (mmd).

The tests were conducted on July 10, 1969, in the vicinity of a natural outbreak of the hemlock looper on the Mount Baker National Forest near Marblemount, Wash. The spray was applied in the early afternoon during a light rain. Due to low clouds and cool temperatures ($\sim 60^{\circ}$ F.), the air was reasonably stable which allowed for good spray coverage of the test area. Nevertheless, foliage in the area was very wet, a factor that should be considered in the evaluation of results.

Two methods were used to evaluate the performance of the formulation against the hemlock looper: (1) the effect on larvae on small hemlock trees, and (2) the effect on larvae on specially arranged foliage on small platforms fully exposed to the spray.

Fifteen stations were established over a 6-acre area in a former clearcut. At each station we located a single hemlock tree 7 to 10 feet in height, erected a pair of wooden platforms (fig. 1), and put a plastic drop cloth under each tree to catch larvae dropping from the foliage (fig. 2A). The platform was a 16-inch-square of 1/4-inch plywood mounted on a short post 4 to 5 feet above the ground. A wire rack was attached to the platform to support several small branches of hemlock foliage about 4 inches above the surface. A tanglefoot barrier around the edge of the plywood prevented the escape of healthy larvae (fig. 2B).



Figure 1.--One of 15 stations consisting of one small hemlock tree and two paired platforms used for evaluating effect of stabilized pyrethrins on hemlock looper.

A



B



C



Figure 2. --Field techniques for evaluation used at each station. **A**, Hemlock tree with plastic drop cloth for catching paralyzed and killed larvae; **B**, platform with wire rack for supporting foliage with larvae fully exposed to spray; **C**, platform covered with plastic bag used as a control during spraying of test area.

Before treatment, the trees and platforms were stocked with hemlock looper larvae, most of which were in the second and third instars, which had been collected previously from the surrounding natural infestation. One hundred larvae were placed on each of the 15 trees 4 hours before spraying and 20 larvae on each of the 30 platforms one-half hour prior to spraying. One platform at each station was used as a control and covered with a light plastic bag during spraying (fig. 2C). The bag was removed about 1 hour after spraying.

Effectiveness of the spray was evaluated by determining the initial knock-down of larvae and by later separation of those actually dead from those showing sublethal effects. Knockdown refers to larvae that were paralyzed by the spray and either dropped off or became lodged in the foliage. It was determined from a tally of all larvae that dropped off the foliage at intervals of 15 minutes, 30 minutes, and 1, 2, 3, and 4 hours after spraying. Larvae which had not dropped from the foliage after 4 hours were dislodged by shaking the tree. Sublethal knockdown was distinguished from mortality by collecting fallen larvae in separate 8-ounce cartons for each time interval and observing them later. The study was terminated 19 hours after spraying when all larvae in the cartons were examined and classified according to whether they were dead, paralyzed, or apparently fully recovered.

RESULTS

Of the larvae placed on trees, only 69 percent or 1,032 of 1,500 could be accounted for in the final count. By comparison, 91 percent (273 of 300) of larvae placed on treated platforms and 88 percent (265 of 300) of larvae placed on control platforms were recovered. Predatory ants on the trees probably removed many of the larvae shortly after the trees were stocked. Other larvae unaccounted for could have been lost in the folds of the plastic drop cloth or become firmly lodged in the wet foliage.

Four hours after spraying, 94 percent of the larvae on trees and 99 percent on the treated platforms were either dead or paralyzed by the treatment, compared with only 6 percent on the control platforms. Sixty-three percent of the larvae on the trees and 75 percent on the platforms actually dropped off the foliage.

The actual patterns of drop off are shown by the solid lines in figure 3. Drop off occurred much quicker from exposed foliage on platforms than from trees. The knockdown pattern can only be estimated because many affected larvae became lodged in the foliage where they could not be tallied until the final count. If the pattern of knockdown was similar to the pattern of actual drop off, it can be estimated by apportioning the total number of dead or paralyzed larvae in the final tally according to the drop off pattern. The knockdown pattern so calculated is shown by the broken lines in figure 3.

More than 90 percent of the drop off on platforms occurred during the first 30 minutes after spraying; therefore, the estimated pattern of knockdown is probably nearly correct for larvae on exposed platforms. However, we can only speculate on the knockdown pattern for trees. If multilayered foliage on

the trees partially screened the spray, knockdown could have been delayed either because the amount of spray which came in direct contact with the larva initially was inadequate for rapid knockdown or because the pyrethrins displayed residual activity on the foliage. In either case a gradual pattern of knockdown would have occurred similar to the estimated line for trees in figure 3. If there was no screening effect, the pattern of knockdown on trees may have been similar to that on exposed platforms, in which case the delay in drop off might have been due to larvae being temporarily lodged in the wet foliage.

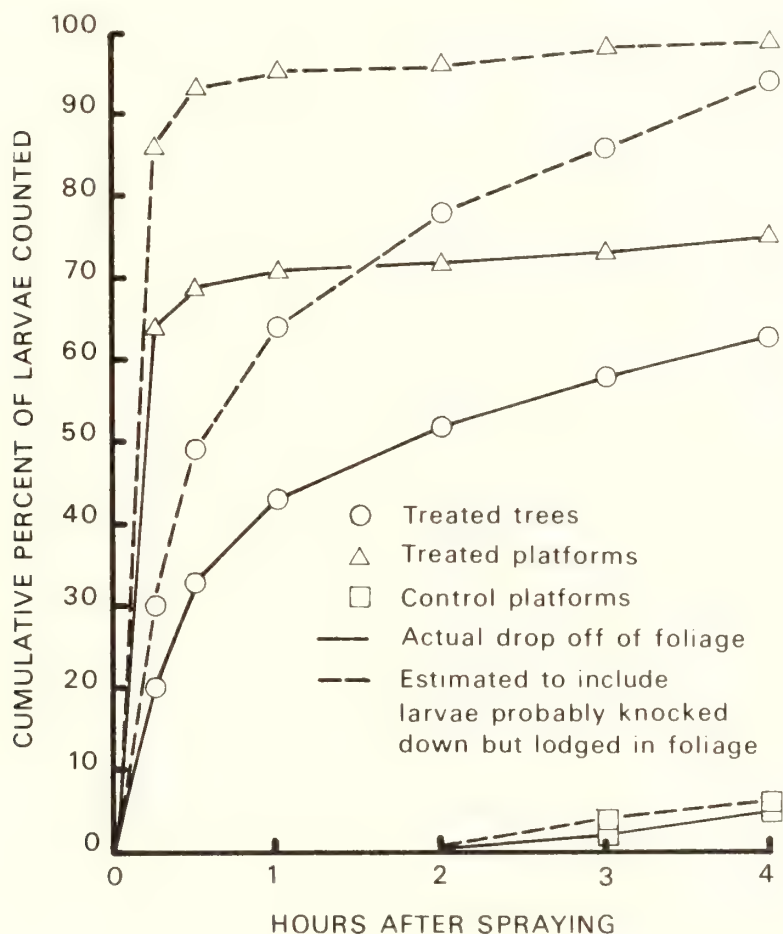


Figure 3.--Drop off from foliage and estimated knockdown of hemlock looper larvae in relation to time after spraying.

Nineteen hours after treatment, a final examination and classification were made of larvae collected during the test. The conditions of these larvae are summarized in table 1. On the treated platforms which had been fully exposed to the spray, 96 percent of the larvae were either dead or paralyzed 19 hours later. By comparison, only 70 percent of the larvae from trees were dead or paralyzed, and 29 percent appeared to have recovered or were unaffected. Total mortality of larvae on the platforms was almost twice that of larvae on trees. These results imply that the lag in drop off of larvae from trees shown in figure 3 was probably due to the initial screening effect of branches which delayed knockdown, not to lodging of larvae in the foliage.

The severity of injury to larvae in relation to the time that they dropped off the trees may be an indication of the differences between the effect of direct contact and delayed action. As shown in figure 4, the most severe injury was incurred by larvae that were knocked down within 15 minutes after treatment. These larvae had most certainly been in direct contact with an effective amount of the initial spray. Moreover, their rates of death, paralysis, or recovery were somewhat similar to those of larvae on exposed platforms (table 1). Larvae that dropped from the test trees at later times seemed to be less severely injured, as indicated by an increase in their recovery rate and a general decline

Table 1.--Condition of test larvae 19 hours after spraying

Treatment and condition	Dropped off foliage		Remainder		Total	
	Number	Percent	Number	Percent	Number	Percent
Trees:						
Dead	144	22	95	25	239	23
Paralyzed	345	53	143	38	488	47
Recovered	163	25	78	21	241	23
Unaffected	0	0	64	17	64	6
Total	652	100	380	101	1,032	99
Treated platforms:						
Dead	80	39	32	46	112	41
Paralyzed	121	59	30	43	151	55
Recovered	3	1	5	7	8	3
Unaffected	0	0	2	3	2	1
Total	204	99	69	99	273	100
Control platforms:						
Dead	2	15	0	0	2	1
Paralyzed	0	0	0	0	0	0
Recovered	11	85	3	1	14	5
Unaffected	0	0	249	99	249	94
Total	13	100	252	100	265	100

in the rates of death and paralysis (fig. 4). Such evidence suggests that there was late knockdown due to delayed or residual action of the insecticide, but that the severity of injury diminished with further lapse of time after treatment.

CONCLUSIONS

Our test demonstrated that the stabilized formulation of pyrethrins could be extremely effective against the western hemlock looper when delivered under a field situation. However, degree of effectiveness seemed to be influenced markedly by the initial amount of exposure to the insecticide. Knockdown was faster and mortality was higher among larvae fully and directly exposed to the spray than among larvae partially screened in the foliage of small trees. Moreover, rate of recovery was considerably higher among larvae that did not receive ample spray for rapid knockdown. Effectiveness of the stabilized pyrethrins in a natural forest situation will obviously depend to a large extent on the thoroughness with which the insecticide can be delivered to the target insect.

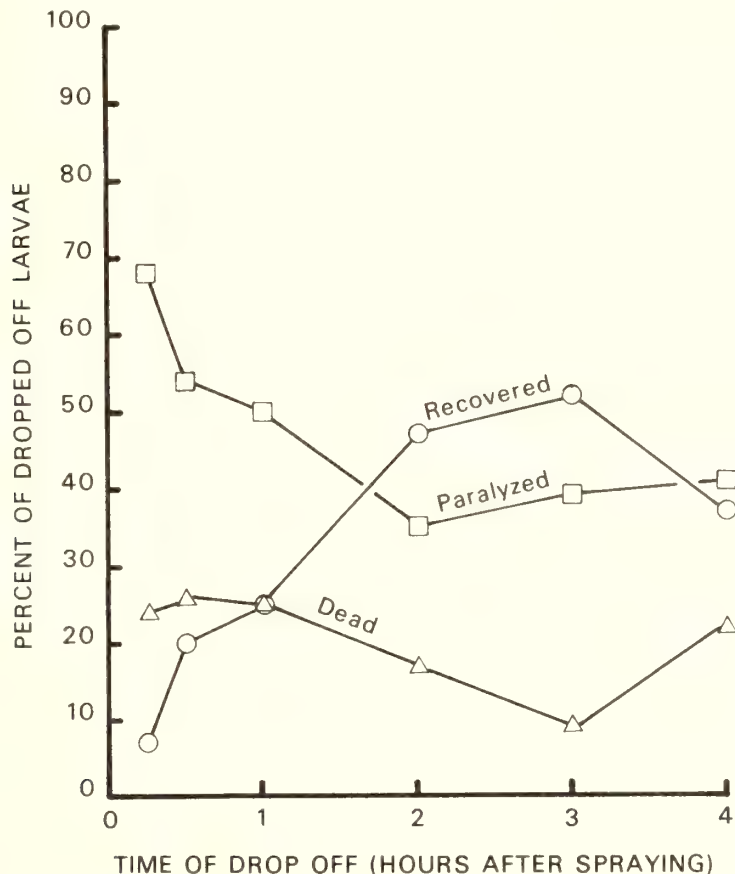


Figure 4.--Condition of larvae 19 hours after spraying in relation to time of drop off from trees.

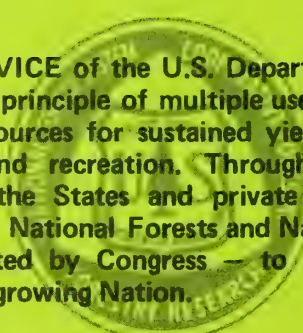
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Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

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